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UNIVERSITY OF LONDON
QUESTIONS.

QUESTIONS

IN

CHEMISTRY

AND

NATURAL PHILOSOPHY,

GIVEN AT THE

MATRICULATION EXAMINATION OF THE
UNIVERSITY OF LONDON,
FROM THE YEAR 1864 TO JANUARY, 1881.

CLASSIFIED ACCORDING TO THE SYLLABUS OF SUBJECTS OF
EXAMINATION.

BY

C. J. WOODWARD, B.Sc.,

LECTURER ON CHEMISTRY AND PHYSICS, BIRMINGHAM AND MIDLAND INSTITUTE.

NEW EDITION, CONTAINING ANSWERS.

BY PERMISSION.

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PREFACE.

In preparing candidates for the Matriculation Examination of the University of London, I have used a MS. copy of the Questions given in the Calendar, classifying them under the different headings stated in the Syllabus of subjects, published by the Senate of the University.

My collection has now grown to dimensions such, that I think, if printed, it may be useful to many who are engaged in teaching the subjects to which the questions refer, as well as to those candidates for Matriculation who have not the advantage of special instruction.

The mode of using these questions must be left to the discretion of the teacher or the student, but the following plan seems to me best :—

After a subject as *e. g.* "The Composition and Resolution of Statical Forces" has been read through in any text book, let the candidate work the whole of the questions given under this head. Similarly with the "Simple Machines" and other subjects.

It is a fair inference that if a candidate can, *without help* work all, or nearly all, the questions which have been set for the last ten years, he will be likely to pass the examination of the eleventh year. Should a student find, after going through any division of the subject in his text book, he is unable to work the questions here given under that head, he may be sure his book is not sufficiently advanced, or, what is more likely, he has not properly mastered it. Let him then go over the subject a second or third time until the questions can all be worked satisfactorily.

Although this work is intended primarily for candidates preparing for the Matriculation Examination of the University of London, the author believes it will be found useful in preparing for the Oxford Middle Class and other examinations, and also as a general exercise book in Mechanical Philosophy and Chemistry.

C. J. W.

Birmingham, November 1873.

PREFACE TO SECOND EDITION.

THE Questions from 1874 to January 1881 have been added. Answers are appended when they can be stated concisely, and the cumbersome method of printing the date of each question is replaced by a continuous numbering under each head of the syllabus, an index at the end giving all information as to position of questions in the Examination Papers. I have to thank Mr. George Smith, B.Sc., for help in working out answers, and also for assistance in revising proof sheets.

Birmingham and Midland Institute,
Birmingham, March, 1881.

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CHEMISTRY OF THE NON-METALLIC ELEMENTS :—

Including their compounds as enumerated below—their chief physical and chemical characters—their preparation and their characteristic tests.

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Nitrogen	D
Chlorine	E
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Iodine	G
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Carbonic Acid, Carbonic Oxide	R
Oxides and Acids of Nitrogen	S
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Olefiant Gas, Marsh Gas	U
Sulphurous and Sulphuric Acids	V
Sulphuretted Hydrogen	W
Hydrochloric Acid	X
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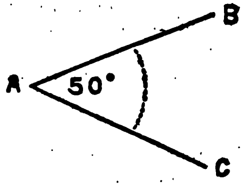
Not classed under previous heads	A'

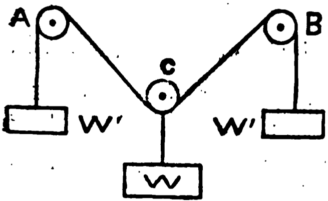
NATURAL PHILOSOPHY.

A.—MECHANICS.

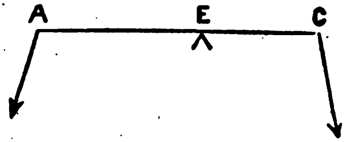
COMPOSITION AND RESOLUTION OF STATICAL FORCES.



1. Let AB and AC represent in direction and magnitude two equal forces acting at A, the angle between their directions being 50°. Draw a line which shall represent in direction and magnitude a force which will be in equilibrium with these forces; and state the angle which its direction will make with AB.

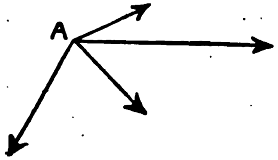


2. A weight, W, is suspended from a moveable pulley C, A and B being 2 fixed pulleys. When the system is at rest, what are the forces which keep the point C in equilibrium? and why is it necessary that the two weights W′, should be equal to one another?



3. Two forces represented in magnitude and direction by AB and CD, act at the extremity of a lever AC. Exhibit by means of a diagram the moments of these two forces round the fulcrum E, and state what condition will be satisfied when there is equilibrium.

4. A plummet, the string being held in the hand, is immersed in a current of water, and the string ultimately settles in a somewhat slanting position. Explain by a diagram the nature and action of the forces which determine the position of the string.



5. Exhibit by means of a diagram, of which the construction is to be explained, the method of finding the resultant of the forces represented by the lines in the annexed figure, the forces all acting at the point A, and lying in the plane of the paper.

6. A boat is moored in a stream by two ropes, fixed to posts, one on each bank, and inclined to the direction of the current, at angles of 30° and 45°. Draw a figure from measuring which the proportion may be found between the strains on the ropes.

7. Three strings are tied in a knot; the ends of two of them are fastened to pegs; and the third has a known weight attached to it. Give a construction for finding the forces pulling the pegs; and from the construction show to what these two forces respectively become almost equal when one of the supporting strings is almost long enough to allow the other to hang in a vertical position.

8. It is required to substitute, for a given vertical force, two forces, one horizontal, the other inclined at an angle of 45° to the vertical; determine the magnitude of these two forces.

9. Show how to find the resultant of two forces, A and B, which act upon a given point in directions that make an angle a with each other. The force A acting towards the given point, and the force B away from it.

Six vertical smooth posts are fixed in the ground at equal intervals round the circumference of a circle, and a cord, without weight, is passed twice round them, all in a horizontal plane, and pulled tight with a force of 100lbs. Find the magnitude and direction of the resultant pressure on each post.

10. State and explain the proposition known as the "Parallelogram of Forces."

A weight of 24lbs. is suspended by two flexible strings, one of which is horizontal, and the other is inclined at an angle of 30° to the vertical direction. What is the tension in each string?

11. If two forces acting on a point are represented in magnitude and direction by two sides of a triangle, under what circumstance will the third side exactly represent their resultant? Forces of 20 and 10 act along the sides AB and BC respectively of an equilateral triangle: find the magnitude of their resultant.

12. Show how to find the resultant of three given forces acting on a point; and prove that to produce equilibrium, their directions must be in the same plane.

13. What is meant by the moment of a force about a given point? How is its magnitude determined? If several forces which do not balance, act in the same plane upon different points of a solid body, one point of which is fixed, what condition must be fulfilled in order that the body may be in equilibrium? Show that this condition cannot be fulfilled unless the fixed point is in the plane of the forces.

14. Show that as the angle between two forces is increased their resultant is diminished. Two forces of the magnitude 5 and 11, act at angles of 60°, 90°, and 120°, respectively. Compare their resultants in the three cases.

15. Assuming the principle of the parallelogram of forces, show what must be the relation, in order that there may be equilibrium on the inclined plane, between the power, the weight, and the pressure against the plane.

16. Show *why* a lever is in equilibrium when the power and weight are to each other inversely as the perpendicular distances of their lines of action from the fulcrum.

17. Show how to resolve a given force into two components, one of which has a given magnitude and acts parallel to a given straight line.

As a special case, resolve a force of magnitude 12, acting horizontally from left to right, into two components, one of which is a force of magnitude 25, acting vertically upwards.

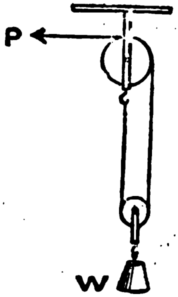
18. Three equal forces act in one plane on a point in such a way that each of them makes an angle of 120° with each of the other two. Prove that the forces will balance.

19. Employ the above proposition to show that the resultant of forces, 7 and 14, acting at an angle of 120°, is the same as the resultant of forces 7 and 7 acting at an angle of 60°.

20. When a horse is employed to tow a barge along a canal, the tow-rope is usually of considerable length; give a definite reason for using a long rope instead of a short one. Show whether the same considerations hold good in relation to the length of the rope when a steam tug is used instead of a horse.

21. Show how it is possible for a sailing-vessel to make way in a direction different from that of the wind. Why cannot a round tub be steered at as great an angle to the direction of the wind as a long boat?

22. In a combination of one fixed and one moveable pulley, when the power acts horizontally, and the fixed end of the string is attached to the upper block, find the direction of the total resultant pressure on the upper block and its magnitude as compared with the power. (See fig.)



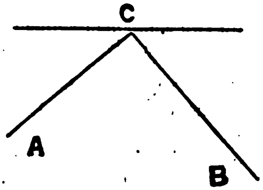
23. A heavy plummet is immersed in a stream, the string being held by a person standing on the bank; the string is found to settle in a sloping position. Show by means of a sketch the three forces which keep the plummet in equilibrium.

24. State the Parallelogram of Forces. Explain the meaning of the terms employed in your statement. Apply it to show that if four forces acting on a point be represented by the sides of a rectangle taken in order, they will be in equilibrium.

25. Explain the meaning of the words Composition and Resolution of Forces; and show how forces may be compounded and resolved.

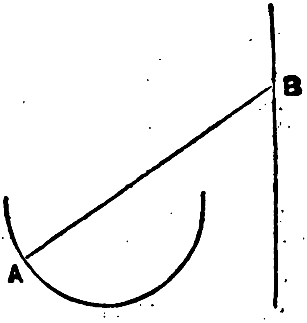
A particle is acted on by a force whose magnitude is unknown, but whose direction makes an angle of 60° with the horizon. The horizontal component of the force is known to be 1·35. Determine the total force, and also its *vertical* component.

26. Assuming the truth of the Parallelogram of Forces, show how to find the position and magnitude of the resultant of two parallel forces P and Q, acting at different points of a rigid body.



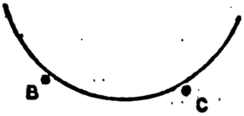
27. Two uniform heavy rods AC, BC, rigidly connected together, are capable of turning round a horizontal axis at C. Find the mechanical conditions which determine the position of equilibrium.

28. State and exhibit the mechanical conditions of equilibrium, when a beam AB of uniform thickness and density rests with one extremity against a smooth vertical wall, and the other against a smooth hemispherical bowl.

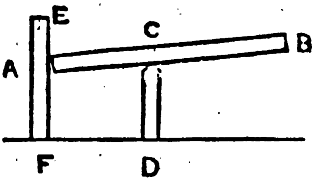


29. Two parallel forces P and Q act at two points in a straight line 6 inches apart in opposite directions. Their resultant is a force of 1 lb, acting at a point in the line 4 feet from the larger of the forces P and Q. Determine the value of P and Q.

30. A uniform circular arc rests in a vertical plane on two smooth pegs B and C. Find by aid of a sketch the mechanical conditions of equilibrium.



31. A heavy uniform beam AB is supported at the point C by the vertical prop CD, its extremity A pressing against a wall EF. Determine the conditions of equilibrium, taking no account of friction.



32. Show that when five forces, acting at a point are capable of being represented in magnitude and direction by the sides of a pentagon taken in order they are in equilibrium.

33. By aid of a sketch explain the resolution of forces in the case of a ship sailing at right angles to the wind, exhibiting also the force that causes lee-way.

34. Three cords are tied together at a point. One of these is pulled in a northerly direction with a force of 6 lbs., and another in an easterly direction with a force of 8 lbs. With what force must the third cord be pulled in order to keep the whole at rest?

35. By aid of a sketch explain the resolution of forces in the case of a paper kite suspended in the air at the end of a string.

36. A sphere of wood, loaded at one point with lead, rests upon a plane inclined at 30° to the horizon, being prevented from sliding down by the friction of the plane. State and explain by a diagram the conditions of equilibrium.

37. A body, whose mass is 5 kilogrammes, resting upon a smooth plane inclined at 30° to the horizon, is acted on by four forces; (1) its weight, (2) the reaction of the plane, (3) a force equal to the weight of two kilogrammes, acting parallel to the plane and upwards, and (4) a force P, acting at an angle of 30° to the plane. Determine the value of P, that the body may be in equilibrium.

38. Explain the action of the rudder in turning a vessel at sea?

39. A ladder rests against the side of a house and is inclined at 60° to the ground. The pressure of the ladder against the wall being equal to a force of 60, and the friction at the same place equal to a force of 40. Find the *pressure* and *friction* at the point where the ladder rests on the ground. Find also the *weight* of the ladder.

40. Explain what is meant by the moment of a force. Prove that when two forces act on a point, the algebraic sum of their moments about any point in their plane is equal to the moment of their resultant about the same point.

41. State the condition in order that three or more forces acting on a bar which is free to turn about a fixed axis may not produce motion about that axis.

A uniform bar 2 ft. long, and weighing 3 lbs., is used as a steelyard, being supported at a point 4 in. from one end. Find the greatest weight which can be weighed with a moveable weight of 2 lbs., and find the point from which the graduations should be measured.

42. Show by aid of a sketch exhibiting the resolution of forces, *how* a ship can sail at right angles to the direction of the wind.

43. Define the moment of a force about a point, and state the condition necessary for the equilibrium of a body free to turn about a fixed axis.

In a common steelyard whose mass is 20 lbs., the point of suspension of the body to be weighed is 4 inches from the fulcrum, while the centre of gravity of the beam is one inch from the fulcrum measured in the opposite direction. If the mass of the sliding weight be 7 lbs., find the distances from the fulcrum of the graduations marked respectively 14 lbs., 28 lbs., 56 lbs., and 112 lbs.

44. Explain what is meant by the "Triangle of Forces." Show how it is derived from the "Parallelogram of Forces." Employ it to determine the tensions when a mass of 10 lbs. is attached to a point

of a string whose ends are fastened to two points five feet apart in a horizontal line, the lengths of the parts into which the string is divided by the weight being 3 feet and 4 feet respectively.

45. Define force. What is meant by the resultant of a number of forces? Give a geometrical construction for finding the resultant of any number of forces acting at a point.

46. Define the moment of a force about a point. Show how to find the resultant of two parallel forces which act in opposite directions, but not in the same straight line.

47. State the conditions necessary for the equilibrium of a body free to move in one plane. To what do these conditions reduce when one point in the body is fixed?

48. Explain the meaning of the proposition known as the "Parallelogram of Forces"

Three forces act along three of the sides of a parallelogram ABDC, one from A to B, one from A to C, and the third from B to D, each force being proportional to the side along which it acts; the parallelogram is such that the diagonal AD is perpendicular to the side BD. Find the line of action of the resultant force, and show that its magnitude is equal to one of the given forces.

B.—SIMPLE MACHINES.

(Mechanical Powers).

RATIO OF THE POWER TO THE WEIGHT IN EACH.

1. What is the ratio between the power and the weight in a screw which has ten threads to the inch, and is moved by a power acting perpendicularly to an arm at a distance of one foot from the centre.

2. Two men, A and B, carry a weight of 200 lbs. on a pole between them. If the men be 5 feet apart, and the weight slung at a distance of 2 feet from A, what part of the weight will he bear, neglecting the weight of the pole?

3. If a man has to raise a weight, and has only one pulley at his disposal, show how he must apply it in order to obtain the utmost advantage.

4. A man who weighs 160 lbs., wishing to raise a rock, leans with his whole weight on one end of a horizontal crowbar five feet long, which is propped at the distance of four inches from the end in contact with the rock. What force does he exert on the rock; and what pressure has the prop to sustain?

5. Sketch a system of pulleys in which the power is to the weight in the proportion of 1 to 4.

6. State the relation between the power and the weight in the inclined plane, the power acting parallel to the plane.

How may this relation be deduced from the consideration of an endless chain put round the inclined plane and hanging down?

7. Find the ratio between the power and the weight in a screw with 10 threads to the inch, worked by a lever 1 foot long.

Mention some of the most important applications of the screw.

8. A weight is to be raised by means of a rope passing round a horizontal cylinder 10 inches in diameter, turned by a winch with an arm 2½ feet long. Find the greatest weight which a man could so raise without exerting a pressure of more than 50 lbs. on the handle of the winch.

9. Sketch a system of pulleys, one fixed and two moveable, in which one end of the string passing round each pulley is attached to the weight; and find the relation of the power to the weight when in equilibrium.

10. A straight lever 20 inches long weighs 15 ozs. Where must the fulcrum be placed in order that the lever may be in equilibrium, when a weight of 16 oz. is hung at one end, and a weight of 9 oz. at the other?

What is the pressure on the fulcrum when the lever is in equilibrium?

11. How can the true weight of a body be determined by means of a balance with unequal arms?

12. Describe the screw, and point out its relation to the inclined plane.

What is the mechanical advantage of the screw?

13. In a system of one fixed and four moveable pulleys, in which one end of each string is fixed to a beam, find the relation between the power and the weight (neglecting the weight of the pulleys) when one of the strings is nailed to the pulley around which it passes.

What is the force exerted on the beam to which the strings are attached?

14. Find the ratio of the power to the weight for equilibrium on a bent lever of the first kind, when the forces act at right angles to the arms. Supposing the arms make an angle of 120° with each other, and have the relative lengths 1 and 5, find the magnitude and point of application of the resultant of the power and weight when the lever is in equilibrium.

15. Find the relation between the power and the weight in the third system of pulleys (in which each string is attached to the weight), when the weights of the pulleys are disregarded. Also show what the relation would be if the weights of the pulleys were taken into account.

16. What condition must be fulfilled in order that a body may be in equilibrium, upon a hard smooth plane surface?

A weight rests upon a smooth horizontal plane, and is acted on by a force, equal to a weight of 6 lbs., in a direction inclined obliquely downwards at an angle of 30° to the horizon. Find the magnitude of horizontal force required to prevent motion.

17. A weight of 56 lbs. is attached to a straight lever without weight, at a distance of 3 inches from the fulcrum, and is balanced in one case by a power of 6 lbs., and in another by a power of 16 lbs. Find in each case the pressure on the fulcrum, and also the distance between the points of application of the power and weight when they are applied,

(*a*) On the same side of the fulcrum.

(*b*) On opposite sides of the fulcrum.

Show how the answer to each part of the question would be affected if the lever weighed 9 lbs., and its centre of gravity were at the fulcrum.

18. A solid roller, with an axle projecting from one end, is suspended horizontally from two vertical cords—one of them attached to the end of the roller opposite to the axle, the other to the middle of the axle ; the roller is 4 feet long, and weighs 27 lbs. ; the axle is 1 foot long and weighs 1 lb. Find the weight supported by each cord.

19. A pole 12 feet long, weighing 25 lbs., rests with one end against the foot of a wall, and from a point 2 feet from the other end a cord runs horizontally to a point in the wall 8 feet from the ground. Find the tension of the cord and the pressure of the lower end of the pole.

20. A wheel and axle is used to raise a bucket from a well. The radius of the wheel is 15 inches ; and while it makes 7 revolutions, the bucket, which weighs 30 lbs., rises 5½ feet, show what is the smallest force that can be employed to turn the wheel. Upon what general principle is your answer founded ?

21. A man wheels a loaded wheelbarrow along a level road. Point out the conditions which determine how much of the total weight of load and barrow is supported by the wheel, and how much is supported by the man.

22. If a man wants to help a cart up hill, is there any mechanical reason why he should put his shoulder to the wheel, instead of pushing at the body of the cart ? and if so, show at what part of the wheel force can be applied with the greatest effect.

23. A body weighing 6 lbs. is placed on a smooth plane, which is inclined at 30° to the horizon. Find the two directions in which a force equal to the weight of the body may act to produce equilibrium. Also, find what is the pressure on the plane in each case.

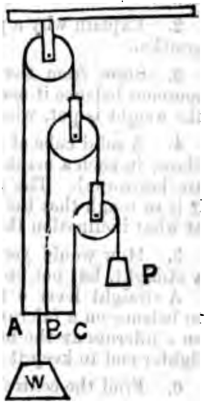
24. Ten weights, each of 20 lbs., are to be lifted to a height of 8 ft. from the ground. Show how a system of pulleys might be arranged so that disregarding friction and the weight of the pulleys, all the weights could be lifted together, by exerting a force equal to one of them. Show that the distance through which this force would have to act, would be the same as when the weights were raised one by one by the same power.

25. Two men carry a block of iron weighing 176 lbs., suspended from a uniform pole 14 feet long; each man's shoulder is 1 foot 6 inches from his end of the pole. At what point of the pole must the heavy weight be suspended, in order that one of the men may bear four-fifths of the weight borne by the other?

26. A substance is weighed from both arms of an unequal balance, and its apparent weights are 9 lbs. and 4 lbs., find the ratio between the arms.

27. Find the relation between the power P and weight W in the system of pulleys represented in the figure, neglecting the weight of the strings, of the rod ABC, and of the pulleys.

If the pulleys are $1\frac{3}{4}$ inches in diameter, and the strings parallel and attached at given points A, B, and C, to the rod supporting the weight, to what point of the rod should the weight W be attached, so that the horizontal direction of the rod may be maintained?



28. In a system of pulleys in which a separate string passes round each pulley, it is found that when the power and the weight are in equilibrium, and the power is caused to descend through 8 feet, the weight rises through 1 foot. Can the mechanical advantage of this arrangement ever be as much as 8? Give reasons for your answer.

29. It is asserted that if a substance be weighed successively from the two ends of a false balance, its true weight will equal the square root of the product of the two apparent weights. Prove this.

30. Assuming the truth of the Parallelogram of Forces, deduce from it the conditions of equilibrium of parallel forces applied to a lever.

31. Enunciate precisely the law of "virtual velocities," and apply it to determine the conditions of equilibrium in the single moveable pulley with inclined strings, and in the screw.

32. State the principle of the "Triangle of Forces." Employ it to construct an inclined plane on which a horizontal force of 3 lbs. will support a weight of 4 lbs., and find the resistance of the plane.

33. Make careful sketches of *(a)* a system of weightless pulleys in which 1 lb. balances 32 lbs., and *(b)* a system of weightless pulleys in which 1 lb. balances 15 lbs., taking care in each case that the number of pulleys is the least possible.

34. Describe some form of balance in which the beam is below the scale-pans.

A body appears to weigh 24 lbs. when placed in one scale-pan, and 25 lbs. when placed in the other, find its real weight to three places of decimals.

C.—CENTRE OF GRAVITY.

1. Explain why a man who has to carry a heavy box in one hand must throw his body on one side.

If the force of gravity, instead of acting vertically, were to act horizontally from east to west, would this affect the position within a body of its centre of gravity?

2. Explain why a plumb-line will not remain at rest except in one position.

3. Show from the property of the Centre of Gravity that in a common balance it makes no difference in what part of the scale-pan the weight is put, whether in the centre or at the edge.

4. A solid cube of wood rests by one of its sides upon an inclined plane, in such a manner that the upper and lower edges of its base are horizontal. The inclination of the plane can be increased; and it is so rough that the cube will topple over before it will slide. Find at what inclination this will take place.

5. How would you find, experimentally, the centre of gravity of a straight, but not uniform rod?

A straight lever 6 feet long, and heavier towards one end, is found to balance on a fulcrum 2 feet from the heavy end; but when placed on a fulcrum at the middle, it requires a weight of 3 lbs. hung at the lighter end to keep it horizontal. What is the weight of the lever?

6. Find the centre of gravity of a system consisting of two spheres, 8 oz. and 24 oz. in weight, connected by a rigid rod without weight, the distance between the centres of the spheres being 1 foot.

7. Define the centre of gravity of a body.

A triangular board is hung by a string attached to one corner. What point in the opposite side will be in a line with the string?

8. A cylinder is placed on one of its ends on a horizontal plane sufficiently rough to prevent sliding, and is gradually pulled by a string attached to its upper end until it falls over. What part of the upper surface is just over the point of contact of the base with the plane when this takes place?

9. A B C D E is a board of irregular figure, and it is found that when the board is hung from A, the point C is in the vertical line through A, and that when it is hung from B, the point D is in the vertical line through B. If the board be suspended vertically from the point E, find what point in the perimeter will lie vertically below E?

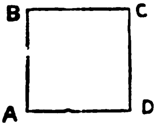
10. Draw a four-sided figure with unequal sides, and describe (1) a geometrical, and (2) an experimental, method of finding its centre of gravity.

A piece of uniform paper in the form of a regular hexagon has one of the equilateral triangles, obtained by joining the centre to two consecutive angular points, cut out. Determine the position of the centre of gravity of the remainder of the paper.

11. A cylindrical vessel weighing 4 lbs., and the internal depth of which is 6 inches, will just hold 2 lbs. of water. If the centre of gravity of the vessel, when empty, is 3·39 inches from the top, determine the position of the centre of gravity of the vessel and its contents when full of water.

12. Two uniform cylinders of the same material, one of them 8 inches long and 2 in diameter; the other 6 inches long and 3 in diameter, are joined together end to end, so that their axes are in the same straight line. Find the centre of gravity of the combination.

13. Two heavy particles, weighing respectively 3 and 5 ounces, are attached to the ends of a straight rod 8 inches long, weighing 2 ounces. Find the centre of gravity of the system.



13*a*: Four heavy particles of the relative weights 2, 3, 4, and 5, are placed at the corners A, B, C, and D, respectively, of a horizontal square board; find the common centre of gravity of the 4 particles. Show whether the centre of gravity would change if the board were inclined.

14. Give examples of bodies in stable, unstable, and neutral equilibrium. If a body be in stable equilibrium, how is its centre of gravity affected by a small displacement of the body?

15. Equal weights (each 1 oz.) are placed at the angular points of a heavy triangular lamina, and also at the middle points of the sides. Find the position of the centre of gravity of the plate and weights.

16. A short circular cylinder of wood has a hemispherical end. When placed with its curved end on a smooth table, it rests in any position in which it is placed. Determine the position of its centre of gravity.

17. Squares are described upon the three sides of an isoceles right angle triangle. Determine the centre of gravity of the complete figure so formed.

18. What is meant by the centre of gravity of a substance? Define stable, unstable, and neutral equilibrium in the case of a body of convex surface resting on a horizontal plane; and state the connexion between the description of equilibrium of such a body and the position of its centre of gravity.

19. Exhibit and explain by means of a sketch a method of determining, experimentally, the centre of gravity of an irregular, flat, heavy plate.

20. Define stable, unstable, and neutral equilibrium, and state the conditions of stability of a body resting on a horizontal plane.

21. A telescope consists of 3 tubes, each 10 inches in length, sliding within one another, and their weights are 8, 7, and 6 ounces. Find the position of the centre of gravity, when the tubes are drawn out to their full length.

22. What is the centre of gravity of a body? A line is drawn across an equilateral triangle, of 12 inches side, parallel to its base, and so as to cut off one-fourth of its area. Find the distance of the base from the centre of gravity of the remainder.

23. A solid right circular cone of homogeneous iron is 64 inches in height, and its mass is 8,192 lbs. The cone is cut by a plane perpendicular to the axis, so that the mass of the small cone removed is 686 lbs. Find the height of the centre of gravity of the truncated portion remaining, above the base of the cone.

24. Show that the centre of gravity of three equal weights placed at the angles of a triangle coincides with the centre of gravity of the triangle. A B C is an equilateral triangle of 6 inches side, of which O is the centre. If the triangle O B C be removed, find the distance from A to the centre of gravity of the remainder.

D.—GENERAL LAWS OF MOTION.

WITH THE CHIEF EXPERIMENTS BY WHICH THEY MAY BE ILLUSTRATED.

1. Enunciate the second law of motion.

A ball is projected in a horizontal direction from a rifle placed 1,000 feet above the level of the sea. Find the elevation of the ball above the level of the sea two seconds after the discharge, neglecting the resistance of the air.

2. State the third law of motion; and give a numerical application of it.

Explain the "kick" of a gun.

3. When a body in motion is left wholly to itself, not being influenced by gravity or any other external force, what is the nature of the motion of translation of the body? Give some evidence from observation or experiment of the truth of your statement.

4. Explain the terms "force," "weight," "pressure," and "tension."

5. Distinguish between the statical and dynamical measures of force. How are they related to one another?

6. A body of given mass is acted upon by a constant force. Find the space described in a given time.

If a particle move from rest through 40·5 feet in 4½ seconds under the action of a constant force, find the acceleration.

7. What is meant by the "acceleration" due to a force; and upon what does its magnitude depend?

If the velocity of a body increase from 12 feet to 13 feet per second, while it moves over a distance of 5 feet, what is the acceleration? Indicate the course of reasoning upon which your calculation is based.

8. A mass originally at rest, acted on by a force which in $\frac{1}{32}$ of a second, gives to it a velocity of $5\frac{1}{4}$ inches per second; show what proportion the force bears to the weight of the mass.

9. A particle moves with a uniformly increasing velocity. Show that the whole space described is proportional to the square of the time from the beginning of the motion.

10. Explain the Third Law of Motion.

Apply it to determine the velocity gained per second, when weights of 6 oz. and 4 oz. are attached to two ends of a string, passing over the edge of a table, the larger weight being drawn along the table by the smaller, which descends vertically.

11. Force may be defined as "any cause which tends to change a body's state of rest, or of uniform motion in a straight line." Mention any forces you know of, and show how this definition applies to them. What is Inertia? Is it a Force?

12. If a particle moves in consequence of the continued action upon it of a constant force; show what is the character of the resulting motion, and in what manner it depends on the magnitude of the force, and the mass of the particle.

As a special case, show how the resulting motion would be changed if the mass of the particle were trebled, and the intensity of the force acting upon it were doubled.

13. When a particle, which is acted upon by any number of forces, moves during their action with uniform velocity in a straight line, show what condition the forces must fulfil.

14. The speed of a railway train increases uniformly for the first three minutes after starting; and during this time it travels one mile. What speed (in miles per hour) has it now gained; and what space did it describe in the first two minutes?

15. In the last question, supposing the line level, and disregarding friction and the resistance of the air, compare the force exerted by the engine with the weight of the train.

16. Which could you throw the farthest, a small ball of lead, or a ball of cork of the same size; and why?

17. The intensity of gravity at the surface of the planet Jupiter, being about 2·6 times as great as it is at the surface of the earth, find, approximately, the time which a heavy body would occupy in falling from a height of 167 feet to the surface of Jupiter.

18. State the three laws of motion, and give examples of each. A rifle is pointed horizontally with its barrel 5 feet above a lake. When discharged, the ball is found to strike the water 400 feet off. Find, approximately, the velocity of the ball.

19. Find the tension on a rope which draws a carriage of 8 tons weight up a smooth incline of 1 in 5, and causes an increase of velocity of 3 feet per second.

20. If, on the same incline, the rope breaks when the carriage has a velocity of 48·3 feet per second, how far will the carriage continue to move up the incline?

21. When a body changes its rate of motion under the action of a constant force, show that the space described in any time is the same as the space described by a body moving uniformly with the mean velocity for the same time.

If a body is projected upwards with a velocity of 120 feet in a second, what is the greatest height to which it will rise, and when will it be moving with a velocity of 40 feet per second?

22. I suddenly jump off a platform with a twenty pound weight in my hand. What will be the pressure of the weight on my arm while I am in the air? Give a reason for your reply.

23. In Attwood's machine one of the boxes is heavier than the other by half an ounce. What must be the load of each in order that the overweighted box may fall through one foot during the first second?

24. A balloon is carried along by a current of air moving from east to west at the rate of 60 miles an hour, having no motion of its own through the air; and a feather is dropped from the balloon. What sort of a path will it appear to describe, as seen by a man in the balloon?

25. Suppose that at the equator a straight hollow tube were thrust vertically down towards the centre of the earth, and that a heavy body were dropped through the centre of such a tube it would soon strike one side. Find which, giving a reason for your reply.

26. A river one mile broad is running downwards at the rate of 4 miles an hour, and a steamer moving at the rate of 8 miles an hour wishes to go straight across. How long will the steamer take to perform the journey, and in what direction must she be steered?

27. It is stated that because the earth rotates on its axis, a lump of lead weighs less in Ceylon than in Spitzbergen. Explain the statement.

28. What is meant by saying with reference to gravity $g = 32$? What would be the value of g if your units of space and time were miles and minutes?

29. A stone is let fall from the top of a railway carriage which is travelling at the rate of 30 miles an hour. Find what horizontal distance and what vertical distance the stone will have passed through in one-tenth of a second.

30. At the earth's equator the hot air ascends and is replaced by cold air which blows in along the ground from the poles. That which comes from our hemisphere blows from the north-east instead of from the north. Explain this.

31. Two masses of 48 and 50 grammes respectively are attached to the string of an Attwood's machine, and, starting from rest, the larger mass passes through 10 centimetres in one second. Determine from these data the value of the acceleration due to gravity, your units being centimetres and seconds.

32. What is meant by saying, with reference to gravity, $g = 32$? What would be the value of g if your units of space and time were miles and hours?

33. There are two chambers, one of which is in the act of dropping freely under gravity down a pit, while the other is made to descend with uniform velocity. A man in each chamber during the descent lets go a stone which he has been holding in his hand. What will be the motion of the stone in each case?

34. Supposing the unit of force to be that force which, acting upon one pound for one second, produces a velocity of one foot per second; state the relation between the unit of force and the weight of one pound.

35. Give an account of the French system of weights and measures, and state accurately the connection between the units of length, capacity, and mass.

36. Explain what is meant by an accelerating force. If an accelerating force is represented by F, when the unit of time is a minute, how will it be represented when the unit of time is a second?

37. The two ends of a string passing over the pulley of an Attwood's machine are loaded as follows: A with 16½, B with 15½ ounces. Find the tension at A when it is in motion downwards.

38. Two bodies start together from rest, and move in directions at right angles to each other. One moves uniformly with a velocity of 3 feet per second, the other moves under the action of a constant force. Determine the acceleration due to this force if the bodies at the end of 4 seconds are 20 feet apart.

39. The space passed over in any time may be represented by an area. Explain clearly the meaning of this statement, and under what conditions it is true. Show how to employ it to determine the space passed over by a body in 10 seconds after it starts from rest and has its velocity increased by 1 foot per second at the beginning of each second.

40. A mass of 488 grammes is fastened to one end of a cord which passes over a smooth pulley. What mass must be attached to the other end in order that the 488 grammes may rise through a height of 200 centimetres in 10 seconds? ($g = 980$.)

41. A mass of 6 ounces slides down a smooth inclined plane whose height is half its length, and draws another mass from rest, over a distance of 3 feet in 5 seconds, along a horizontal table which is level with the top of the plane, the string passing over the top of the plane. Find the mass on the table.

42. State and explain Newton's second law of motion. What is meant by the phrase "change of motion" in connection with that law?

An ounce being taken as the unit of a mass, a second as the unit of time, and an inch as the unit of length, compare the unit of force with the weight of a pound.

43. Equal forces act for the same time upon bodies of different mass. What is the relation between the effects which they produce? Describe fully the unit of force implied in the equation $P = mf$.

44. State your reason for regarding a pound as a unit of mass and not of force. What is the most convenient unit of force when a foot, a pound, and a second are units of length, mass, and time, respectively?

45. Define acceleration, and explain how it is measured. What is the relation between the measure of a force, the mass on which it acts, and the acceleration which it produces?

A body resting on a smooth horizontal table is acted on by a horizontal force equal to the weight of two ounces, and moves on the table over a distance of 10 feet in 2 seconds. Find the mass of the body.

46. A smooth, inclined plane, whose height is one half its length, has a small pulley at the top, over which a string passes. To one end of the string is attached a mass of 12 lbs., which rests on the plane; while from the other end which hangs vertically is suspended a mass of 8 lbs.; and the masses are left free to move. Find the acceleration and the distance traversed from rest by either mass in 5 seconds.

E.—LAW OF THE MOTION OF FALLING BODIES.

1. How far will a body fall from rest in four seconds? With what velocity must a ball be thrown vertically upwards, in order to return to the hand after four seconds?

2. An arrow is shot vertically upwards with a velocity of 100 feet in a second when it leaves the bow. How long will it be before it reaches the ground again?

If another arrow, half the weight of the former, be shot with the same *force* vertically upwards, how long will it be before it reaches the ground again? Point out where you apply any of the laws of motion in answering this question.

3. When a stone has fallen from rest under the action of gravity, we know that at the end of one second of time it is moving with the velocity of 32 feet per second; and yet during the first second it has only fallen 16 feet. How do you reconcile these two statements?

4. How does it appear that the force of gravity acts on all substances alike?

A person inside clings to the roof of a railway carriage, which then rushes horizontally over the edge of a precipice. What change, if any, in his motion will result if he lets go his hold? Give a reason for your reply.

5. Explain by reference to a diagram why a stone only falls 16 feet during the first second, while yet the force of gravity generates in that time the velocity of 32 feet per second.

6. A stone, after falling for one second, strikes a pane of glass, in breaking through which it loses half its velocity. How far will it fall in the next second?

7. A body falling with a uniformly accelerated motion passes through 10 feet in the first two seconds after starting; how far will it be from the starting point at the end of the third second.

8. A heavy particle is dropped from a given point, and after it has fallen for one second, another particle is dropped from the same point. What is the distance between the two particles when the first has been moving during 5 seconds.

9. Through what vertical distance must a heavy body fall from rest, in order to acquire a velocity of 161 feet per second? If it continue falling for another second, after having acquired the above velocity, through what distance will it fall in that time? (Gravity = 32·2.)

10. A balloon has been ascending vertically at a uniform rate for 4·5 seconds, and a stone let fall from it reaches the ground in 7 seconds. Find the velocity of the balloon, and its height when the stone is let fall.

11. If a heavy body is thrown vertically up to a given height, and then falls back to the earth, show that, neglecting the resistance of the air, it passes each point of its path with the same velocity when rising as when falling.

A ball is allowed to fall to the ground from a certain height, and at the same instant another ball is thrown upwards with just sufficient velocity to carry it to the height from which the other one falls. Show when and where the two balls will pass each other.

12. A heavy particle is dropped from a height of $178\frac{8}{9}$ feet above a level plane, and while falling, it is carried horizontally with a uniform velocity of 3 feet per second. At what distance from its starting point will it strike the ground?

13. What is meant by saying that the acceleration produced by gravity is represented by the number 32·2?

From a point in a smooth inclined plane a ball is rolled up the plane with a velocity of 16·1 feet per second. How far will it roll before it comes to rest, the inclination of the plane to the horizon being 30°? Also, how far will the ball be from the starting point after 5 seconds from the beginning of motion?

14. A rifle bullet is shot vertically downwards from a balloon at the rate of 400 feet per second. How many feet will it pass through in two seconds, and what will be its velocity at the end of that time, neglecting the resistance of the air, and estimating the acceleration due to gravity at 32?

15. A body projected vertically upwards against gravity has risen 120 feet in one second. What was its initial velocity of projection, and how far will it rise during the next second?

16. A stone projected vertically upwards reached the ground again in six seconds. What was its height above the ground at the end of the first second? ($g = 32.$)

17. A stone is thrown into the air at an angle of 45° to the horizon with a velocity of 128 feet per second. Show that the path of the stone will not be a straight line; and determine the amount of vertical deviation from a straight line at the end of two seconds, neglecting the resistance of the air. ($g = 32.$)

18. A particle is projected in a horizontal direction with a velocity of 10 miles an hour, and at the same time falls under the action of gravity. Assuming that no other forces are acting, and taking $g = 32$ feet per second, draw a picture representing the position of the particle at the end of 1, $1\frac{1}{2}$, $2\frac{1}{4}$, and 3 seconds.

19. What is the average velocity of a body during the first second of its fall under gravity; also during the first two seconds? Show how, by knowing the average velocity, you can find the whole space fallen through.

20. A body, whose mass is 100 grammes, is thrown vertically upwards with a velocity of 980 centimetres per second. What is the energy of the body (1) at the moment of propulsion, (2) after half a second, (3) after one second? [N.B. $g = 980$ centimetres per second.]

21. A stone dropped into a well reaches the water with a velocity of 80 feet per second, and the sound of its striking the water is heard $2\frac{7}{12}$ seconds after it is let fall. Find from these data the velocity of sound in air. ($g = 32$.)

22. What is meant when it is said that the acceleration of gravity is 32·2 foot-second units?

From what experiments do we conclude that the weight of a body is proportional to its mass?

23. A body is projected up a smooth inclined plane, whose height is one half of its length, with a velocity of 60 feet per second, and just reaches the top. Find the length of the plane and the time taken in the ascent.

24. A body is allowed to fall freely from rest. Find an expression for its velocity at any point in terms of the distance through which it has fallen and the acceleration of gravity. If $g = 981$ centimetre-second units, from what height must a body fall in order that it may have a velocity of 50 metres per second on striking the ground?

25. A heavy body starting from rest, slides down a smooth plane inclined 30° to the horizon. How many seconds will it occupy in sliding 240 feet down the plane, and what will be its velocity after traversing this distance? ($g = 32$.)

26. What is the "Kinetic Energy" of a moving mechanical system?

A shot of 1,000 lbs. moving at 1,600 feet per second strikes a fixed target. How far will the shot penetrate the target exerting upon it an average pressure equal to the weight of 12,000 tons?

F.—HYDROSTATICS, HYDRAULICS, AND PNEUMATICS.

PRESSURE OF LIQUIDS AND GASES, ITS EQUAL DIFFUSION, AND VARIATION WITH THE DEPTH.

1. A mercurial barometer is lowered into a vessel of water so that the surface of the water is finally six inches above the cistern of the barometer. What *kind* of change will take place in the reading of the column of the instrument? Give a reason for your reply.

2. If a bottle filled with air be tightly corked, and lowered into the ocean, the cork will be forced in at a certain depth. Why is this? and what will take place if the bottle be filled with water instead of air?

3. If as much additional air were forced into a closed vessel as it previously contained when in communication with the atmosphere, what would be the pressure on a square inch of the internal surface?

4. At what depth in a lake is the pressure of the water, including the atmospheric pressure three times as great as at the depth of ten feet, on a day when the height of the liquid column in a water-barometer is 33 feet 6 inches?

5. Describe an experiment which proves that the upward pressure of a fluid on any substance immersed in it, is equal to the weight of the fluid displaced by the substance. Give a sketch, showing the arrangement of the apparatus.

6. If a bladder, containing 300 cubic inches of air, under a pressure of equal to that of 30 inches of mercury, be sunk to 240 feet below the surface of water, the barometer at the time standing at 28·5 inches, to what volume will the air in the bladder be compressed? (Specific gravity of mercury, 13·6).

7. If two liquids that do not mix, meet in a level tube, open at both ends, show that when at rest, their heights above the common surface of contact, are inversely proportional to their specific gravities.
The specific gravity of mercury is 13·6, and the height of the mercurial barometer is 30 inches. What is the greatest height to which water can be raised by means of the common pump?

8. A vessel, in the shape of a pyramid, is 5 feet high, and with a base, 4 feet square, is filled with water. Find the pressure upon the base, and account for its being greater than the total weight of water in the vessel.

9. Find the pressure on a vertical rectangle 10 inches long and 6 inches wide, immersed in water, with its longer sides horizontal, and with the upper one 2 inches below the surface. (One cubic foot of water weighs 1,000 ounces).

10. State the law connecting the volumes and pressure of permanent gases at a constant temperature, and describe experiments in proof of it.

11. Explain under what circumstances the pressure of a liquid on the bottom of a vessel containing it, is different from the force with which it presses the vessel against the table on which it rests. Account for this difference of pressure.

12. State the law connecting the pressure of a gas with the weight of a constant volume of the gas.

A tumbler full of air is placed, mouth downwards, under water, at such a depth that the surface of the water inside is at a depth of 25½ feet. Compare the weight of a cubic inch of air in the tumbler with that of a cubic inch of the air outside, the barometer standing at 30 inches, and the specific gravity of mercury being 13·6.

13. If a cylinder, with flat horizontal ends, is wholly immersed in water, prove that the resultant pressure exerted upon it by the water is an upward pressure, equal to the weight of a quantity of water of the same bulk as the cylinder.

14. State clearly the conditions requisite for the ascent of a balloon, and show what would be the effect of a variation of barometric pressure on the lifting power of a balloon partially filled with gas.

Taking 7·67 lbs. as the weight of 100 cubic feet of air, find, approximately, the volume of hydrogen (specific gravity compared with air 0·07) which a balloon must contain, in order that its total lifting power may be equal to the weight of 713 lbs.

15. A litre of air at 0°C. and 760 mm. barometric pressure, weighs 1·293 grammes. Show how to find the weight of 73 litres at the same temperature, and under 1000 mm. pressure.

16. Describe an experiment, showing that the pressure of water, at any depth below its surface, is exerted upwards as well as downwards.

17. In a vessel not quite full of water, and closed at the top by a membrane, a small glass balloon, with an opening under water, contains just sufficient air to make it float. Explain the principle on which the balloon sinks, when the membrane is pressed down. Will it rise or sink with increase of pressure, when the opening is above water?

18. A cylindrical bell 4 feet deep, whose content is 20 cubic feet, is lowered into water until its top is 14 feet below the surface of the water; and air is forced into it until it is three-quarters full. What volume would the air occupy under the atmospheric pressure? The water barometer being at 34 feet.

State the principles on which your answer is based.

19. Describe an experiment by means of which the upward bearing pressure at various depths in a vessel of liquid may be exhibited, and by which also it may be seen that the pressure is proportional to the depth.

20. A square plate, whose area is 64 square inches, is immersed in sea water, its upper edge, which is horizontal, being 12 inches below the surface. Determine the whole pressure of the water on the plate when it is inclined at 45° to the horizon, assuming a cubic inch of sea water to weigh ·63 ounces.

21. How would you prove, experimentally, that when a solid body is immersed in a liquid its loss in weight is equal to the weight of its own volume of the liquid?

22. A vessel, consisting of a decimetre cube, is filled to one-third of its height with mercury, sp. gr. 13·6, while the rest is filled with water. Determine the whole pressure against one of the sides, in kilogrammes.

23. If you have a deep tank or ocean of water the pressure will be greatest at the bottom, and will be diminished by a definite amount for every foot you rise above the bottom. Does this law hold for atmospheric air? If not, in what direction does it differ in this case, and what is the cause of the difference?

24. A wooden vessel 6 inches square and 6 inches in height, with a neck 2 inches square and 3 inches in height, is full of water. Find the position of the centre of gravity of the water. Also find the pressure on the base of the vessel.

25. If the height of the water-barometer be 1033 centimetres, what will be the pressure upon a circular disc, whose radius is 7 centimetres, when sunk in water to a depth of 50 metres? State the pressure in grammes per square centimetre.

26. The resultant vertical pressure of a fluid on the surface of a body immersed in it is equal to the weight of fluid displaced by the body. How is this proved by experiment?

27. A vessel shaped like a portion of a cone is filled with water. It is one inch in diameter at the top, and eight inches at the bottom, and is twelve inches high. Find the pressure (in pounds per square inch) at the centre of the base, and also the whole pressure on the base (A cubic foot of water weighs 1,000 ounces).

28. Distinguish between liquids and gases.

A cylindrical tube a metre in length and having one end sealed contains dry air at the ordinary pressure and temperature. The tube is dipped vertically with its open end downwards into a tank of mercury, till the air within it is compressed to four-fifths of its former volume. Find the distance of the top of the tube from the free surface of the mercury in the tank, the height of the barometer being 750 millimetres.

29. A cubic foot of water may be assumed to contain 1,000 ounces; while a gallon contains 10 lbs. Two gallons of water are placed in a cylindrical can 10 inches in diameter. Find the whole pressure upon the curved surface of the can.

30. Two vertical cylindrical vessels, A and B, are connected at the bottom by a very narrow tube, and stand on a horizontal table. The diameter of A is 6 inches, that of B is 4 inches. A liquid of specific gravity 1·4 fills the cylinders to a height of 6 inches above the base, when an equal volume of water is poured carefully on the top of the liquid in A. Where will the common surface of the liquids be when equilibrium has been restored?

31. The length of a barometer-tube is 80 inches, its diameter is ¼ inch except for one inch of its length, where a cylindrical bulb is inserted so as to increase the diameter of the tube to 3 inches. The bottom of the bulb is 27 inches above the mercury in the tank. The lower portion of the bulb and the tube below contains mercury, the upper part of the bulb and the tube contains water. If the mercurial barometer rise ·5 inch, through what distance will the upper surface of the water move, the specific gravity of mercury being 13·67?

32. What is the resultant pressure of a heavy fluid on a body immersed in it?

An empty balloon with its car and appendages weighs, *in* [illegible], 1,200 lbs. If a cubic foot of air weigh 1¼ oz., how many cubic feet [illegible] gas of specific gravity ·52 must be introduced before the balloon will begin to ascend?

G.—SPECIFIC GRAVITY,

AND THE MODES OF DETERMINING IT.

1. Define clearly what is meant by Specific Gravity. Is there any difference in specific gravity between 4 lbs. of iron and 2 lbs. of the same metal?

A body whose specific gravity is 3·5, weighs 4 lbs. in water. What is its real weight?

2. A solid weighs *in vacuo* 100 grains, in water 85 grains, and in another fluid 88 grains. What is the specific gravity of this fluid?

3. A solid, soluble in water, but not in alcohol, weighs 346 grains in air, and 210 in alcohol. Find the specific gravity of the solid, that of alcohol being 0.85.

4. State precisely what information is gained by knowing the specific gravity of a body.

Show how to find the specific gravity of a solid lighter than water, and not soluble in that liquid.

5. A lump of bees-wax, weighing 2895 grains is stuck on a crystal of quartz weighing 795 grains, and the whole when suspended in water is found to weigh 390 grains. Find the specific gravity of bees-wax, that of quartz being 2·65.

6. A bottle holds 1500 grains of water; and when filled with alcohol it weighs 1708 grains; but when empty it weighs 520 grains. What is the specific gravity of the alcohol?

7. A piece of cupric sulphate weighs 3 oz. *in vacuo* and 1·86 oz. in oil of turpentine. What is the specific gravity of cupric sulphate, that of turpentine being 0·88?

8. A piece of metal weighs 211·6 grains *in vacuo*, 187·32 grains in water, and 182·37 grains in a solution of sodic chloride. Find the specific gravity of the solution.

9. Describe the method by means of which you would determine the specific gravity of a substance in the form of powder, and explain how to calculate the result.

10. If a piece of wood, weighing 120 lbs., floats in water with four-fifths of its volume immersed, show what is its whole volume. (One cubic foot of water weighs 62·5 lbs.)

11. When equal volumes of alcohol (specific gravity, 0·8,) and distilled water are mixed together, the volume of the mixture (after it has returned to the original temperature), is found to fall short of the sum of the volumes of its constituents by 4 per cent. Find the specific gravity of the mixture.

12. Explain how it may be proved, *experimentally*, that the resultant pressure of a liquid on a body immersed in it, is an upward pressure equal to the weight of the liquid displaced. How may this property be employed to compare the specific gravities of two liquids?

13. Describe, fully, an experimental method of determining the weight of a cubic inch of water.

14. Explain the principle which enables us to find the specific gravity of a body by weighing it in water.
A piece of metal of specific gravity 9·8 weighs in water 56 grains. What is its true weight?

15. A body weighs in air 80 grains, in water 56 grains, and in another liquid 46 grains. Find the specific gravity of the liquid.

16. What becomes of the weight which the body in the last question appears to lose?

17. A wine-bottle, which below the neck is perfectly cylindrical and has a flat bottom, is placed in pure water. It is found to float upright with 4½ inches immersed. The bottle is now removed from the water and put into oil, the specific gravity of which is 0·915. How much of it will be immersed in the latter fluid?

18. An inch cube of ice (sp. gr. = 0·918) is floating in water, of which the sp. gr. is 0·99987. Find accurately what will be its height above the surface of the water.

19. How would you find the specific gravity of a body which floats in water?

20. An accurate balance is totally immersed in a vessel of water. In one scale-pan some glass (sp. gr. 2·5) is being weighed, and exactly balances a one-pound weight (sp. gr. 8·0), which is placed in the other scale-pan. Find the real weight of the glass.

21. Explain the methods of determining the specific gravity of a liquid (1) by weighing a sinker in it, (2) by using a specific gravity bottle.

22. An inch cube of a substance of specific gravity 1·2 is immersed in a vessel containing two fluids which do not mix. The specific gravities of these fluids are 1·0 and 1·5. Find what will be the point at which the solid will rest.

23. What is the difference between density and specific gravity?

A rod of uniform section is formed partly of platinum (sp. gr. = 21·0) and partly of iron (sp. gr. = 7·5). The platinum portion being 2 inches long, what will be the length of the iron portion, when the whole floats in mercury (sp. gr. = 13·5) with one inch above the surface?

24. A body weighing 300 grammes (sp. gr. = 5·0) has 100 grammes of another substance attached to it; and the joint weight of the two in water is 300 grammes. Find the specific gravity of the attached substance.

25. Explain, generally, the nature of the corrections that must be applied when a delicate weighing is made in air, showing why it is necessary to read the thermometer and barometer, and to know approximately the specific gravity of the weights and also of the substance weighed.

26. What is meant by specific gravity in general, and particularly according to the French system of measurement? Describe in detail (with a sketch) the method of obtaining the specific gravity of a liquid by means of the specific gravity bottle.

27. Describe the hydrostatic balance, and show how to employ it to determine the specific gravity of a solid heavier than water.

28. A piece of copper and a piece of silver, fastened to the two ends of a string passing over a pulley, hang in equilibrium when entirely immersed in a liquid whose specific gravity is 1·15. Determine the relative volumes of the masses, the specific gravities of silver and copper being respectively 10·47 and 8·89.

29. What are the conditions which must be fulfilled in order that a heavy body may float in a fluid?

A cubic foot of water contains 1,000 oz., and a cubic foot of oil 840 oz. The oil is poured on the top of the water (without mixing), and a sphere whose volume is 36 cubic inches and mass 19½ ozs. is placed in the mixture. How many cubic inches of its volume will be below the surface of the water, the layer of oil being sufficiently deep for the complete immersion of the sphere?

30. How would you determine the specific gravity of a solid lighter than water? A piece of metal weighs 850 grains *in vacuo*, 760 grains in water, and 772 grains in a mixture of alcohol and water. Find the specific gravity of the mixture.

31. What do you understand by the pressure of a fluid at a point?

A cylindrical bucket 10 inches in diameter and one foot high is half filled with water. A half-hundredweight of iron is suspended by a thin string, and held so as to be completely immersed in the water, without touching the bottom of the bucket. Subsequently the string is removed and the iron allowed to rest on the bottom of the bucket. By how much will the pressure on the bottom be increased in each case by the pressure of the iron? (A cubic foot of iron contains 440 lbs., and a cubic foot of water 62½ lbs.

32. How may a hydrometer with a short and slender stem be adapted for the determination of the specific gravities of liquids which differ widely from one another, as, for example, alcohol and concentrated sulphuric acid? Describe Sikes's hydrometer.

H.—THE BAROMETER, SIPHON, COMMON PUMP, FORCING PUMP, AND AIR-PUMP.

1. Draw a diagram representing (in section) a single-barrel air-pump when the piston is being lowered.

Explain the action of such a pump.

If the receiver hold 64 grains of air, and 8 grains be removed by the first stroke of the piston, how much will be removed by the second stroke?

2. Explain why a siphon cannot be used to convey water from a lower to a higher level?

3. Describe by means of a diagram the common pump. State the limit to its action, and the cause of the same.

4. Explain the action of the siphon. Is there any limit to the height of an embankment over which water may be carried by means of a siphon from a higher to a lower level?

5. Explain the action of the ordinary lifting-pump. Find the limit of its action; and show that this will be different at the top of a mountain and at the level of the sea.

6. If a barometer were carried down in a diving-bell, what would take place? Give a rough quantitative result.

7. A tapering tube is bent in the middle at an acute angle, and being filled with water is inverted with the two ends completely immersed beneath the surfaces of the water in two vessels, the narrower leg being held vertical, and its end being only just below the surface. Point out the mode in which the water will flow; and show when the flow will cease.

8. Describe and explain the barometer; and state on what principle it is used to determine the height of a mountain.

Might it also be used to determine the depth of the sea?

9. Describe the forcing-pump; and state why it cannot in general be replaced by a common pump.

10. A barometer tube of half an inch internal diameter is filled in the usual way, and the mercury is found to stand at the height of 30 inches. A cubic inch of air having been allowed to pass into the vacuum above the mercury, the column is found to be depressed 5 inches. What was the volume of the original vacuum?

11. Describe the construction and action of the common pump.

12. A tube closed at one end is filled with mercury, and the open end dipped below the surface of mercury in an open vessel; if the tube be inclined at an angle of 60° to the vertical, what is the greatest length the tube can have so as to remain full of mercury, the length of the barometer being at the time 30 inches?

13. If the height of the barometer rises from 30 inches to 30·25 inches, what is the *increase* of pressure (in lbs.) upon a square foot? The weight of a cubic foot of water being taken to be 1000 ounces, and the specific gravity of mercury 13·55.

14. Describe and explain the action of the common siphon.

15. Describe the common barometer; and point out the principle on which its action is based.
What change in the atmospheric pressure, on a square inch, is indicated by a fall of one inch in the height of the barometer column? (A cubic inch of water weighs 252·7 grains, and the specific gravity of mercury is 13·6.)

16. Describe and explain the construction and action of the double-barrelled air-pump.

17. Describe the forcing-pump, and explain its action. If the area of the piston is 3·5 square inches, and a power of 77 lbs. is employed in forcing it down, find the pressure of the air within the air-chamber, and the height to which water can be raised above the piston, when the surface of the water in the chamber is one foot above the piston. (One cubic foot of water weighs 62·3 lbs.)

18. Describe the barometer-gauge of the air-pump, and explain how the degree of exhaustion of the air in the receiver is determined by it.

19. Describe the siphon, and explain its action. Show whether it would make any difference in its action if the limbs were bent, or of unequal bore.

20. If there were three mercurial barometers, and in the first the space above the mercury is a perfect vacuum, in the second it contains a small quantity of air, and in the third it contains a small quantity of water; state and explain the effect of slightly depressing each of the tubes in the cistern.

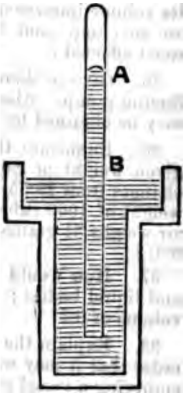
21. Describe the forcing-pump, and explain how it can be made to give a continuous stream.
The area of the piston of a forcing-pump is one square foot. Show what force must be exerted on the piston in order to raise water to a height of 40 feet. (Weight of one cubic foot of water, 62·5 lbs. nearly.)

22. Explain the construction of an air-pump with a single-barrel. What are the objections to an air-pump of this kind, and by what means are they overcome?

23. Describe the common barometer, and state clearly the principles on which its action is based.
What effect is produced on the mercurial column (1) by depressing the tube in the mercury cistern, (2) by inclining the tube.

24. Explain the principle of the siphon, and state the limitations to its action.

25. Forty cubic centimetres of atmospheric air are enclosed in a tube over mercury. The height of the mercury in the tube above the level in the trough outside being 50 centimetres (AB=50). The tube is depressed until AB is equal to 30 centimetres. What is now the volume of the air? (The temperature (15° C.) and the height of the barometer (76 centimetres) have not changed during the observations.



26. Describe the arrangement of the valves in a condensing air-pump.

The capacity of the barrel of a condensing air-pump is 10 cubic inches, and of a copper receiver 100 cubic inches. By how much will the pressure of the air in the receiver be increased after 20 strokes of the piston.

27. What does a barometer measure? At the bottom of a mine a mercurial barometer stands at 77·4 centimetres; what would be the height of an oil barometer at the same place, the specific gravity of mercury being 13·596, and that of oil 0·9?

28. The two limbs of a Mariotte's tube are graduated in inches. The mercury in the shorter limb stands at the graduation 4, and five inches of air are enclosed above it. The mercury in the other limb stands at the graduation 38. The barometer at the time indicates a pressure of 29·5 inches. Find to what pressure the five inches of air are subjected, and also the length of tube which they would occupy under the atmospheric pressure alone.

29. Describe a water-level, and explain how you would use it to determine the difference in level between the top and the bottom of a railway incline.

30. Sketch and describe the common lifting-pump, and state what modifications would have to be introduced in order to make it into a force-pump.

31. What is meant by the height of the barometer? Does the height of the barometer vary when the tube is inclined? If not, why is it essential that the barometer should be vertical when read?

32. By what means is the relation between the pressure and volume of a given quantity of gas determined?

An air-bubble at the bottom of a pond, 10 feet deep, has a volume of 0·00006 of a cubic inch. Find what its volume becomes when it just reaches the surface, the barometer standing at 30 inches, and mercury being 13·6 times as heavy as the water of the pond.

33. Ten cubic centimetres of air are measured off at atmospheric pressure. When introduced into the vacuum of a barometer, they depress the mercury, which previously stood at 76 centimetres, and occupy a volume of 15 c.c. By how much has the mercurial column been depressed?

34. A piece of wood floats in a beaker of water with nine-tenths of its volume immersed. When the beaker is put under the receiver or an air-pump, and the air withdrawn, how is the immersion of the wood affected?

35. Give a sketch, and explain the principle of action of the forcing-pump. Also show by what modification a continuous stream may be obtained by means of it.

36. Enunciate the law connecting the volume and pressure of a given weight of gas. When the height in the mercurial barometer changes from 29·55 inches to 30·33 inches, what is the change in the weight of 1000 cubic inches of air, assuming that 100 cubic inches of air weighs 31 grains, and that the temperature remains constantly at 0°C?

37. How would you show that atmospheric air is heavy like solid and liquid bodies; and how would you find the exact weight of any volume of it?

38. Explain the action of the siphon. What are the conditions in order that it may work properly? If the shorter arm of a siphon for emptying a vessel of water be 32 feet long, and a bubble of air occupy 6 inches of the tube at the end where the water enters, find the changes which the bubble of air undergoes while the process of emptying goes on.

39. Describe the construction and action of (*a*) a force-pump, and (*b*) some form of air-pump.

40. A force-pump, the diameter of whose piston is 6 inches, is employed to raise water from a well to a tank. If the bottom of the piston be 20 feet above the surface of the water in the well, and 100 feet below that of the water in the tank, find the least force which will (1) raise, (2) depress, the piston; friction and the weights of the valves being neglected.

41. A barometer tube of uniform bore is 34 inches in length. A small quantity of air is left by inadvertence above the mercury, so that the barometer registers 30 inches, when the true atmospheric pressure is 30·05. What will be the true barometer reading when this barometer registers 28 inches?

42. A diving-bell is lowered into water at a uniform rate, and air is supplied by a force-pump so as to keep the bell just full without allowing any to escape. How must the quantity (*i.e.*, mass) of air supplied per second be varied as the bell descends?

43. The cylinder of a single-barrelled air-pump has a sectional area of one square inch, and the length of the stroke is 4 inches. The pump is attached to a receiver whose capacity is 36 cubic inches. Compare the pressure of the air in the cylinder after eight complete strokes of the pump, with the pressure before commencing the operation. What conditions limit the amount of exhaustion which an air-pump can affect?

44. Describe fully the adjustment you would make before reading a standard barometer; and state clearly how you would adjust the vernier scale for reading the upper surface of the mercurial column.

K.—OPTICS.

LAWS OF REFLECTION AND REFRACTION.

1. Derive a proof from a common mirror that light is reflected from a surface of glass to a smaller degree than from one of metal.

2. Two concave metallic reflectors are placed facing one another. A candle is placed in the focus of the one, and light is found to be concentrated in the focus of the other. Exhibit in a diagram the course of the rays by means of which this result is caused.

3. Show by a diagram the path before and after refraction of a ray of light which falls upon a plane surface of polished glass; and show also the relation between the angles of incidence and refraction.

4. Objects seen across the top of a limekiln in action appear unsteady and indistinct. What is the cause of this?

5. Apply the laws of reflection to explain the formation of images in a looking-glass.

6. A ray of light AB is at B partly reflected in the given direction BC, and partly refracted. What must be the direction of the reflecting surface at B, and in what plane must the refracted ray lie?

7. A luminous point is placed 3 inches from the surface of a plane mirror, and 5 inches from the surface of a second plane mirror, at right angles to the former. How many images are visible to a person standing in front of both mirrors? Show by a figure the apparent positions of all the images.

8. What is meant by the index of refraction of a transparent medium? Explain by the help of a diagram, a method of tracing the path of a ray of light in a medium—the angle of incidence of the ray upon the surface of the medium and the index of refraction of the medium being known.

9. A straight rod is immersed in water at an angle of 45°, and its lower extremity is at a depth of 6 feet below the surface. Find the apparent position and length of the image of the immersed part. (Index of refraction of water, $\frac{4}{3}$.)

10. A plane mirror revolves about an axis. Explain a method of ascertaining, experimentally, whether or not the axis is perpendicular to the surface of the mirror.

11. Two plane mirrors are inclined at an angle of 60°: trace the path of a pencil of rays proceeding from a luminous point between the mirrors to the eye, after undergoing one reflection at the surface of each mirror.

12. Explain in non-mathematical language what is meant by the "index of refraction" of a transparent medium.

Also describe the phenomenon known as "total reflection"; and show how its occurrence, in a given medium, is connected with the index of refraction of that medium.

13. State the laws of the reflection of light by plane polished surfaces; and explain fully an accurate method of proving them by experiment.

14. State the laws of refraction of light by such substances as water or glass; and describe and explain experiments by which they can be demonstrated.

15. If a small object on the principal axis of a concave mirror, is gradually moved up to the mirror from a point at a considerable distance, show what will be the simultaneous changes in the position and size of the image.

16. Apply the laws of reflection of light to find the apparent position of a luminous point, seen by reflection in a plane mirror.

17. A ray of light is reflected successively by two plane mirrors, the plane of incidence being perpendicular to the line of intersection of the mirrors; prove that when the mirrors are at right angles to each other, the final direction of the ray is parallel to its original direction.

18. When a ray of light falls upon a rotating mirror, show that the reflected ray turns twice as fast as the mirror.

19. A beam of light in passing obliquely from air into water is bent away from the surface of the water, and a straight stick, with one end immersed obliquely, in the water, appears to be bent towards the surface of the water. Show that these are illustrations of the same law of refraction.

20. Enunciate completely (in two statements) the law of reflection of light. Employ it to find the positions of the images of a bright point placed between two parallel plane mirrors.

21. A beam of light issues from a given bright point 3 feet above the surface of still water, and falling obliquely on the surface is divided into two parts, one of which is reflected and the other refracted. Find the position of the point of incidence and its distance from the bright point, so that the reflected and refracted beams may be at right angles to each other.
The index of refraction from air to water is $\frac{4}{3}$.

22. A bright point, 6 inches above the surface of still water, is reflected from the bottom of the vessel, which is 2 feet deep, as well as from the surface of the water. Show how to find the positions of the images formed by the reflections. (Index of refraction $\frac{4}{3}$.)

23. Enunciate by aid of a sketch, and in two statements, the law of refraction when light passes from a rarer to a denser medium. Also point out what is meant by the critical angle.

24. Enunciate completely, by aid of a sketch, the law of refraction. State what you mean by the index of refraction, and what by the critical angle. The index of refraction from air to water is $\frac{4}{3}$. What is the sine of the critical angle in this case?

25. A horizontal ray of light falls in a constant direction upon a plane mirror moveable round a vertical axis, and is reflected from it. Show that if the mirror be turned round, through any angle, the reflected ray will move through double that angle.

26. A person observes his image reflected by a sphere which has a brilliant reflecting surface. Is his image erect or inverted, enlarged or diminished? As he approaches the sphere what changes take place in the appearance of his image?

27. Sketch a concave spherical mirror, exhibiting a distant luminous object, and showing the position and nature of the image of this object given by the mirror. What defects do we mean when we speak of the confusion, distortion, or curvature of an image, apart altogether from the optical causes of these defects?

28. Prove that the apparent depth of a luminous object beneath a surface of water is only three-fourths of its real depth.
The index of refraction of water is $\frac{4}{3}$.

29. Explain the terms, "angle of reflection," "angle of refraction," "critical angle." Is there any displacement of an object which is seen through a sheet of plate glass? Give reasons, aided by a diagram, for your reply.

30. Given a concave spherical mirror, how could you find its radius of curvature by optical means alone, and without resorting to geometrical operations?

31. Enunciate completely, in two statements, the law of reflection of light; and show that both the statements are essential to a complete definition.

32. A ray of light passes from air into glass. The refractive index of glass with regard to air being 1·5. Given the angle of incidence at the common surface, draw a diagram to show how the angle of refraction may be accurately determined.

33. Rays of light from a bright gas-flame pass through a small pinhole in a black screen, and are received on a sheet of ground glass. Describe by the help of a picture the image seen on the glass. What would be the effect of making the pinhole square instead of round?

34. Completely enunciate in two statements the law of reflection of light; and show how to find the chief focus of a concave spherical mirror.

35. Assuming the laws of the ordinary reflection of light, find the position of the image of an object placed in front of a plane mirror, what are the limits of position of the object (the mirror being supposed fixed) so that an image of it may be formed by the mirror?

36. What is meant by the refractive index of a substance? Explain the fact that an aquarium tank appears to be much shallower (from front to back) than it really is; and point out in what way the difference between the apparent and true thickness is connected with the refractive index of the water in the tank.

37. A plane mirror in the shape of a circle, revolves about a vertical diameter. A fixed horizontal ray of light falls upon its centre and is there reflected. Prove generally that if the mirror move through any angle, the reflected ray will appear to have moved through double that angle.

38. If the refractive index of a ray of light in passing from air into water be $\frac{4}{3}$, and in passing from air to glass be $\frac{3}{2}$, find by aid of a diagram what it will be for the ray when passing from water to glass.

39. State, and show how to prove, the law of refraction by plane surfaces.

40. An arrow, pointing towards the observer, is seen by internal reflection in an isosceles right angled prism. Explain the difference in, and give a sketch of, the images seen according as the prism is three-sided or a four-sided Wollaston prism.

41. State the laws of refraction of light, and describe some method of verifying them experimentally.

42. Light proceeds from a point at the bottom of a lake. Make a careful drawing of the pencil of rays after emergence from the water, and find the geometrical focus of the pencil.

43. What is the critical angle of a transparent medium ? Describe what a fish would see on looking towards the surface of the water in directions differently inclined to the horizon, and illustrate your description by a diagram.

44. State the laws of refraction of light. Explain clearly by aid of a diagram why the bottom of a lake appears nearer to the surface than it really is.

45. How would you experimentally verify the laws of refraction ? What condition is necessary in order that a ray of light may be able to emerge from the plane surface of a refracting medium ?

46. Show by a drawing how you would employ a right-angled isosceles glass prism to bend a beam of light at right angles. Will any light be lost at the hypothenuse ? State fully the reason for your answer.

L.—FORMATION OF IMAGES BY MIRRORS AND SIMPLE LENSES.

1. Define the focal length of a lens. If you were given a convex lens, explain how you would proceed to find its focal length. Would your method succeed if the lens were concave ? Give a reason for your answer.

2. Show by diagrams why an object appears larger when viewed through a double-convex lens, but less when viewed through a double-concave lens

3. When you use a lens for magnifying an object, as in a pair of spectacles, the object seen does not appear inverted, but when you use it for the purpose of throwing the image of the flame of a candle upon a screen, the image appears inverted. Explain this.

4. Draw a good figure representing the course of a pencil of rays from a luminous point at some distance, through a convex lens, the point being in the axis.

If a plane mirror were held at the focus to which the rays are brought, and perpendicular to the axis of the lens, where would it send the rays?

5. Explain how a convex lens of short focal length enables one to see minute objects magnified.

6. Explain how to find, experimentally, the focal length of a convex lens.

If a small object and its image be at a distance of 6 and 2·5 inches on opposite sides of the lens, find the focal length of the lens.

7. The image of a lamp flame is to be formed upon a screen, at a distance of 6 feet by means of a convex lens. What is the greatest focal length admissible? With a lens of such focal length what relation will the size of the image bear to the size of the flame?

8. Describe the action of a convex lens upon the following rays proceeding from a luminous point outside the principal axis:—

(*a*) A ray passing through the principal focus nearest to the luminous point.

(*b*) A ray passing through the optical centre.

(*c*) A ray parallel to the principal axis.

Show how to find, approximately, by tracing the paths of two rays from each extremity of the object, the position and size of the image formed by a convex lens.

9. If a candle is placed at a distance of 6 feet from a wall, and a distinct image of the flame is produced upon the wall by a lens held at one foot from the candle, show that a distinct image will also be produced, when the lens is 5 feet from the candle; and compare the sizes of the two images.

10. Explain how to draw a figure to represent the formation of a real magnified image of a small object by a lens. If a real image, five times as high as the object, is to be thrown on a screen at a distance of 36 inches from the object, show what must be the focal length of the lens employed.

11. An object is moved from a considerable distance, on the principal axis of a convex lens up to the lens. Find the corresponding changes in the position and size of the image.

12. A simple lens is used as a magnifier. Sketch the relative positions of the object (an arrow) and its image.

The same lens is used as in photography. Sketch the relative positions of the object and its image.

13. A candle flame is placed at a distance of three feet from a concave mirror formed of a portion of a sphere, the diameter of which is 3 feet. Determine the nature and position of the image of the candle flame produced by the mirror, and state whether it is erect or inverted.

14. What is meant by the focal length of a convex lens? Show how to find it (1) by aid of the sun, (2) by an artificial flame.

15. A pocket lens is used to magnify a small object. Explain why (1) the lens and object are brought close together, and (2) the observer's eye must be generally close to the lens.

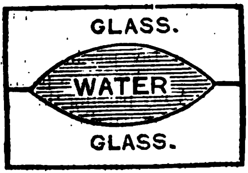
16. When an object is to be photographed, an image of it is first obtained on a ground-glass screen by means of the lens of the camera. Describe the nature and position of this image, and explain its formation.

17. Given the focal length of a convex lens, explain generally how it is possible to find the size of the image of the sun which such a lens will give. In what respect will this image be altered by diminishing the area of the lens without altering its curvature?

18. The chief focal length of a lens is 12 inches; how far must I place a luminous object from the lens, in order to obtain an image twice as large every way as the object?

19. Describe the two main categories under which lenses may be classified.

A lens of water, as in the figure, is enclosed in a rectangular envelope of glass. What kind of lens will the combination form?



20. An object 6 inches long is placed symmetrically on the axis of a convex spherical mirror, and at a distance of 12 inches from it. The image formed is found to be 2 inches long. What is the focal length of the mirror?

21. A man, six feet high, sees his image in a plane mirror hung on a wall. The top of the mirror being six feet from the ground, determine its smallest length in order that the man may see his full-length image in it.

22. Show how to find the position of the image of an arrow placed in front of a concave spherical mirror. Explain when it is an erect and when an inverted image.

23. Explain the formation of images by a concave cylindrical mirror. Find the relation between the distances of the two conjugate foci from the mirror. What is the position of the image of a point which is at the distance of the diameter from the reflecting surface of the cylinder?

24. An object is placed in front of a concave mirror. Show how to determine by a geometrical construction the position of its image, and whether it is erect or inverted.

25. A convex lens of 6 inches focal length is placed at a distance of a foot from a luminous circle an inch in diameter. A convex spherical reflector of one foot radius is placed coaxial with the lens and circle and at a distance of 22 inches from the lens. Where will images of the circle be formed, what will be the lengths of their respective diameters, and will they be erect or inverted ?

26. A small object is placed in front of a concave spherical mirror of 6 inches radius, at a distance of 4 inches from the surface of the mirror. Where will its image be situated ? Will it be erect or inverted, and what will its dimensions be, compared with those of the object ? Where must the object be that the image may be of the same size ?

27. What is the focal length of a lens, and how would you determine it experimentally ? In the case of a convex lens, if the object be as near as possible to the image, where must the lens be ?

28. What is the focal length of a lens ?

A circle an inch in diameter, a convex lens whose focal length is 6 inches, and a second convex lens whose focal length is 10 inches are placed so as to have a common axis. The distance from the circle to the first lens is 20 inches, and from the first lens to the second 36 inches. What images of the circle will be formed ? where will they be situated ? and what will be their dimensions ?

29. Explain the formation of images by means of a concave spherical mirror. How would you determine the focal length of such a mirror ?

30. Explain the formation of an image by a convex mirror. The radius of a convex mirror is 6 inches. If the linear dimensions of an object be twice those of its image, where must each be situated ?

HEAT.

M.—SOURCES OF HEAT.

N.—EXPANSION.

1. One gallon of air (277¼ cubic inches) is heated under constant pressure from 0°C. to 75°C. Calculate the volume of the air at the latter temperature, assuming the co-efficient of expansion to be 0·00366.

2. At what temperature is water at its point of greatest density ? What effect would continuous frosty weather have on our lakes and rivers if the water expanded and contracted according to the same rule as a piece of solid iron ?

3. A room is calculated to hold 60 cubic metres of air at 10°C., and 700 millimetres pressure. What would be the volume of this same quantity of air, if it were measured at 0°C. and 760 millimetres pressure?

4. One hundred cubic centimetres of air at 0°C. are heated to 300°C. under constant pressure. What will be the volume of the air at the higher temperature, if the co-efficient of expansion is 0·00366?

5. Define the terms "co-efficient of expansion," and "mean co-efficient of expansion."

If the coefficient of expansion of atmospheric air for the centigrade scale be $\frac{1}{273}$, find the temperature to which 500 cubic centimetres of air (measured at 15°C.) must be raised in order that its volume may become 700 cubic centimetres, no change of pressure taking place meanwhile.

6. Describe an apparatus by which the coefficient of expansion of a gas may be found. 500 cubic centimetres of oxygen gas are measured when the temperature is 20°C., and the temperature is then raised to 40°C., the pressure meanwhile remaining invariable. What is the volume of the oxygen at the latter temperature? (The coefficient of expansion of oxygen is $\frac{11}{3000}$.)

7. A thousand cubic inches of air at a temperature of 30°C. are cooled down to zero, and at the same time the external pressure upon the air is doubled. What is its volume reduced to, the coefficient of expansion of air for 1°C. being 0·00366?

8. State, precisely, the law which regulates the connection between the temperature and the pressure and volume of a gas, and show that the statement of this law will be the same, whether we study the increase of volume of a gas whose pressure is constant, or the increase of pressure of a gas whose volume is constant.

9. Explain the phrase "mean coefficient of linear expansion of a substance between 0° and t°;" and show that the coefficient of cubical expansion of a metal is very approximately equal to three times its coefficient of linear expansion.

10. What is meant by the "point of maximum density" of water? Sketch and describe an apparatus by which this point may be determined.

11. Describe some accurate method of determining the coefficient of linear expansion of a steel bar. If the expansion of steel is $\frac{2}{3}$ that of brass under the same change of temperature, what will be the best arrangement of rods of these metals to form a gridiron pendulum?

12. What is meant by the real expansion and apparent expansion of a liquid? Explain how to determine the apparent expansion of mercury.

O.—THERMOMETERS.

RELATIONS BETWEEN DIFFERENT SCALES IN COMMON USE.

1. What degree of Centigrade corresponds to —40°F.? (Give the details of the calculation.) What degree Fahrenheit corresponds to 85°C.?

2. What degree of the Centigrade scale corresponds to 85° F.? and what degree of Fahrenheit scale to —40° C.?

3. Express the temperature of 40° Fahrenheit on the Centigrade scale; and express the temperature of —40° Centigrade on the Fahrenheit scale.

4. What temperature on the Centigrade scale corresponds to —40° F.? Show how you obtain the answer. A given liquid is found to boil and distil at 200° C., at the ordinary atmospheric pressure (760 mm.), undergoing at the same time partial decomposition. How could you cause the liquid to boil at a lower temperature, allowing of its being distilled without decomposition?

5. How is a thermometer graduated? Describe the three scales in common use. Express —30° F. and + 327° F. in terms of the Centigrade scale.

6. Describe the process of filling and closing a mercurial thermometer. It is sometimes found that when a mercurial thermometer is placed in melting ice, the temperature indicated is not zero, but a fraction of a degree above zero. How is this explained?

7. Suppose that you wish to verify the accuracy of a Centigrade Thermometer at its freezing and boiling points. Describe in detail how you would proceed to do so. Which point would you commence with? Give a reason for your reply.

8. If the bulb of a thermometer with a fine stem be immersed in hot water, it is sometimes noticed that the mercury falls before it begins to rise. Explain this.

9. Define temperature. Having filled and sealed a mercurial thermometer, how would you determine the freezing and boiling points upon its stem, and how will the positions of these points change with the lapse of time?

10. Show how to convert temperatures expressed in the Centigrade scale into degrees Fahrenheit and *vice versa*. The number expressing the temperature of a body in degrees Fahrenheit is double that expressing it in degrees Centigrade. Find the temperature.

P.—DIFFERENCE BETWEEN TEMPERATURE AND QUANTITY OF HEAT.

1. Why do we generally speak of *degrees* of temperature, but *quantities* of heat?

"If two bodies are in thermal equilibrium with the same body, they are in thermal equilibrium with one another." How would you prove this statement experimentally?

Q.—SPECIFIC AND LATENT HEAT.

CALORIMETERS, LIQUEFACTION, EBULLITION, EVAPORATION.

1. Let a mixture of ice and water be placed in a room of which the temperature is 70° F. What indications will be obtained from a thermometer immersed in the mixture as long as some ice remains? Explain the result.

2. Explain the relation between the boiling point of a liquid and the pressure of the atmosphere. Illustrate your explanation by two or three examples.

3. A piece of iron is heated to 100° C. by prolonged immersion in boiling water. Describe the apparatus which you would employ, and the operations which you would perform in order to determine the quantity of heat given off by the iron in cooling to 0° C.

4. Water is said to boil at the top of Mont Blanc at 86° C.; on Mount St. Bernard at 92° C.; and in London at about 100° C. Explain fully the causes of these differences.

5. What weight of ice at 0° C. will be melted by one kilogramme of water at 40° C., the heat of fusion of ice being taken as equal to 80° C.? (One kilogramme = 1000 grammes.)

6. Describe the principle of the process you would adopt for the determination of the specific heat of a metal.

1000 grammes of water are heated 0·114° C. by the heat given off when 100 grammes of iron are cooled from 20° to 10°. Calculate from these data the specific heat of iron.

7. One kilogramme of ice at 0° C. and 3 kilogrammes water at 79° C. are mixed in a closed vessel the sides of which are supposed impervious to heat. What will be the temperature of the water after the melting of the ice? (Latent heat of water 79°.)

8. You find by experiment that the heat of the flame of a single spirit-lamp is sufficient to boil 6 ounces of water at 100° C. in an open evaporating dish. Two flames, each having the same size and temperature as the one first mentioned, are not able to render the water and escaping steam hotter than the single flame was able to render them. Why not?

How much steam at 100° C. is required to raise the temperature of 54 ounces of water from 0° C. to 100° C., the latent heat of steam being taken = 540° ?

9. One pound of boiling water at 100° C. is placed in contact with one pound of mercury at 0° C. ; heat is transmitted from the water to the mercury, till both are at the same temperature. Calculate this temperature in degrees of the Centigrade scale. (Specific heat of mercury, 0·033.)

10. The heat produced by the complete combustion of one gramme of carbon, in a calorimeter, can convert 100 grammes of ice at 0° C. into water at 0° C. How many grammes of water could be raised by the same amount of heat from 0° C. to 1° C. (Latent heat of water 80.)

11. How much ice at 0° C. can be converted into water at 0° C., by an ounce of steam at 100° C., if we assume heat to be transmitted from the steam only to the ice ? (Latent heat of water 80. Latent heat of steam 536.)

*12. Define the dew point, and describe any instrument by which it may be found.

13. It is found that a kilogramme of water at 100° C. mixed with a kilogramme of melting snow, without loss of heat gives two kilogrammes of water at 10·3° C. Show how to find from this the latent heat of water.

14. Water is boiled in two tubes, the depth of water in the one being 6 inches, and in the other 24 inches. I find that at a temperature when bubbles of steam rise from the bottom of the one tube they do not rise from that of the other. Explain this.

15. Distinguish between *Heat* and *Temperature*. Compare the quantity of heat necessary to heat one pound of water from 0° to 1° C., with the quantity necessary to convert one pound of ice at 0° C. into steam at 100° C. (Latent heat of water 79·25. Latent heat of steam 536.)

16. Of four barometer tubes standing in the same cistern of mercury one has the ordinary Torricellian vacuum, while the other three have, respectively, a little water, a little alcohol, and a little ether in their Torricellian chambers. Will these additions (all of small weight) cause any perceptible change in the lengths of the various columns ? Give a reason for your reply.

17. A glass flask filled with boiling water and steam is corked, and immediately removed from the source of heat. It will presently cease boiling. If now cold water be poured over that part of the flask filled with steam, it will commence boiling again. Give a full explanation of this, and a complete enunciation of the law made use of in your explanation.

18. What is a calorimeter ? Sketch and describe the calorimeter of Laplace, commonly called the ice calorimeter.

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* Should be inserted in Class R. Error discovered too late for correction.

Q 19–29

19. A pound of common salt and a pound of water, both at temp. 15° C. are mixed together, and the salt dissolved. Does any change of temperature take place? Give reasons for your answer.

20. It is found as a result of experiment that 25 grammes of copper, at a temperature of 100° C., are just sufficient to melt 2·875 grammes of ice at 0° C., so that water and copper are finally at 0° C. Find from these data the specific heat of copper, taking the latent heat of water to be 80.

21. Water may with care be cooled down to a temperature considerably below zero without freezing; but when agitated, some of it freezes, and its temperature rises to zero. How do you explain these phenomena?

22. The specific heat of mercury is said to be $\frac{1}{30}$; what does this mean? If the heat yielded by *one* kilogramme of water in cooling down from 100° C. to 0° C. were employed in heating ten kilogrammes of mercury initially at $-20°$ to what temperature would it raise it?

23. State the laws of the boiling of liquids. Explain in what way these laws have been made use of to determine the relation between the pressure and temperature of the vapour of water.

24. Distinguish between a gas and a vapour. Is Boyle's law obeyed by a vapour?

A vessel contains 2 cubic inches of water and 50 cubic inches of steam at 100° C., and at atmospheric pressure. What change will take place in the pressure when the volume of steam is diminished to 25 cubic inches, without any change of temperature?

25. State fully what information we gain from the statement that the specific heat of copper is 0·095, and that the latent heat of water is 80? What is the connection between the specific heat of a body and the rate at which it cools in a chamber which is kept at 0° C.?

26. Distinguish between evaporation and ebullition, and define the boiling point of a liquid.

The maximum pressure of aqueous vapour at 80° C. is 354 mm. A vessel of water at 80° C. is introduced into a receiver containing dry air at the same temperature and at a pressure of 200 mm. By working an air pump and by supplying heat both the pressure and temperature are kept constant. Describe fully what will take place.

27. What is meant by the latent heat of steam? Describe some method by which it can be determined, mentioning the chief precautions which must be taken in carrying it out.

28. Distinguish between evaporation and ebullition, and define the boiling point. How is the pressure of aqueous vapour in a saturated space affected by the presence of air or other gases?

29. Define the Latent Heat of Fusion of a substance.

The latent heat of fusion of ice is 79·5. Its specific gravity is ·917. Ten grammes of metal at 100° C. are immersed in a mixture of ice and water, and the volume of the mixture is found to be reduced by 125 cubic millimetres without change of temperature. Find the specific heat of the metal.

30. What is the Dew-point?
Explain why two volumes of air at different temperatures, neither of which is saturated with aqueous vapour, may, when mixed, produce a cloud.

31. Define *latent heat*, *specific heat*, *capacity for heat*, *coefficient of cubic expansion*, and *thermal conductivity*.
How would you determine the capacity for heat of a copper vessel?

32. Distinguish between evaporation and ebullition. What condition determines whether a liquid will boil or evaporate?
A closed vessel is half full of water and half full of dry air, all at 0° C. and at ordinary pressure. On heating the vessel the pressure is found to rise to two atmospheres, though the temperature is several degrees below 100° C. Account for this.

See also O 4.

R.—CONDUCTION, CONVECTION, RADIATION.

1. When the rooms of a house are heated by means of hot water or hot air, the heat is said to be transmitted by *convection* from the furnace to the rooms of the building; while if you place your hand upon a piece of hot iron the heat is communicated by *conduction* from the metal to your body.
Explain what is meant by the terms *convection* and *conduction*.

2. A basin contains a layer of mercury and one of water. You immerse your hand in such a way that one part of it is in the mercury, and the other in the water. Explain why the mercury feels colder than the water, although both liquids are at the same temperature.

3. I look at a uniform furnace through a long cylindrical tube held close to my eye, and, as I recede from the furnace, I find no falling off in the light and heat which reach my eye, until I am so far from the furnace that I can see more than it through the tube. Explain this.

4. A source of heat is applied equally to the extremities of two similar bars, one of copper and one of iron; and on each bar there is a piece of phosphorus two inches from the source of heat. That on the copper takes fire first. Does this experiment entitle us to conclude that copper has greater thermal conductivity than iron? If not, explain in what respect it is deficient, as a proof.

5. A plate of glass, two-tenths of an inch in thickness, will not, when heated to 100° C. and then put before a thermopile, radiate more than a plate whose thickness is only one-tenth of an inch. But if rock-salt be used, the plate of double thickness will radiate decidedly more than that of single thickness. Explain the difference.

6. What is the cause of the deposition of dew? State the various circumstances which influence this deposition and show why they do so.

7. Define the absolute conductivity of a substance. A metal plate a quarter of an inch in thickness and two feet square, has the whole of one face in contact with water which is kept boiling, while the other face is in contact with melting ice; and it is found that 300 lbs. of ice are melted in one hour. Find the absolute conductivity of the metal, stating clearly the units you employ.

8. Distinguish between conduction, convection, and radiation. Describe some method of comparing the thermal conductivities of metals.

9. How would you compare the thermal conductivities of brass and copper?

Two equal cylinders, one of iron and the other of bismuth, are covered with wax and simultaneously placed on end on a hot metal plate. At first the melting of the wax advances most rapidly on the bismuth bar, but when it has melted about an inch up the cylinder the iron overtakes the bismuth, and then the melting advances more rapidly on the iron bar. Account for these phenomena.

10. Describe an experiment which shows that the absorbing power of a surface is proportional to its radiating power for the same rays. How do you account for the apparent radiation of cold?

11. Explain the formation of dew, stating the conditions which are favourable to its deposition, and why they are so.

How do you account for the efficiency of a glass fire-screen, while the interior of a greenhouse is rendered much hotter than the air outside by the sun's rays alone?

See also Q 12 and 30.

A 1-9

CHEMISTRY.

CHEMISTRY OF THE NON-METALLIC ELEMENTS; INCLUDING THEIR COMPOUNDS AS ENUMERATED BELOW—THEIR CHIEF PHYSICAL AND CHEMICAL CHARACTERS—THEIR PREPARATION—AND THEIR CHARACTERISTIC TESTS.

A.—OYYGEN.

1. Describe the preparation of oxygen from chlorate of potash. Give symbols of the decomposition. By what means can oxygen be separated from atmospheric air, and obtained in a pure form?

2. Four bottles, containing oxygen, hydrogen, nitrogen, and chlorine, respectively, are given to you, with the request to determine the nature of the gas in each bottle. How would you distinguish each of these gases from the others?

3. Describe some of the most important natural substances in which oxygen is contained; and explain the preparation of the gas from the black oxide of manganese. Name the substances which are formed when carbon, hydrogen, phosphorus, and sulphur, respectively, are burned in an excess of oxygen.

4. Describe how you would distinguish oxygen from common air. What class of bodies do we call oxides? Name some oxides of an acid nature and some basic oxides.

5. Describe and explain the preparation of oxygen from potassic chlorate; and name the substances which are formed when carbon, hydrogen, sulphur, and phosphorus, are respectively burned in an excess of oxygen. Which of the following bodies can be burned in oxygen:—sulphur, nitrogen, coke, sulphurous acid, wax, iodine, chlorine and ammonia?

6. Describe by equations, as many processes as you know, for the preparation of oxygen gas.

7. A given sample of gas is found to have the property of kindling a glowing splint of wood. Enumerate the reactions by which you would decide whether it consists of oxygen or of nitrous oxide.

8. Describe how you would prepare pure oxygen; and give an outline of the leading properties of this element.

9. Describe and explain the preparation of oxygen from mercuric oxide. Oxygen is said to be a permanent gas and a great supporter of combustion. Illustrate each statement by a description of one or two experiments.

10. A watch-spring is burned in a closed vessel of oxygen. State (*a*) whether the weight of the bottle and its contents is affected by the combustion; (*b*) what is the nature of the product formed by the combustion; (*c*) whether the grey metallic-looking globules found at the bottom of the bottle after the experiment consist of metallic iron; (*d*) whether the whole of the oxygen originally filling the bottle is still present, and if so, in what forms.

11. Explain by chemical formulæ three distinct methods by which oxygen gas can be prepared.

12. Describe the preparation of oxygen from potassic chlorate. How many ounces of oxygen can be obtained from 115 ounces of potassic chlorate.

13. Explain by means of symbols the decomposition of mercuric oxide by heat. Why are oxygen and mercury considered to be chemical elements?

14. Describe how you would ascertain by experiment whether a gas composed of one volume of nitrogen and one volume of oxygen is a mechanical mixture or a chemical compound of the two elements. Describe and explain the preparation of oxygen from potassic chlorate.

B.—HYDROGEN.

1. Describe the preparation of pure hydrogen. How would you prove that hydrogen is lighter than air? What substance is formed when hydrogen is burnt in air or in oxygen?

2. How would you prepare the following gases—hydrogen, chlorine, and nitrogen? Give in each case an explanation of your process.

3. Describe how you would prepare hydrogen from water without the assistance of an acid; and explain your process. How can a mixture of two volumes of hydrogen and one volume of oxygen be converted into water?

4. Describe how you would prepare hydrogen from water, zinc, and sulphuric acid; and explain your process by means of symbols. Sketch the leading properties of hydrogen, and enumerate native compounds of this element.

5. How would you show that water is formed when hydrogen is permitted to burn in air? How would you extract oxygen from water? Explain your process.

6. Describe how you would prepare hydrogen from water, and explain your process. Two bottles, one filled with hydrogen and the other with marsh-gas, are given to you with the request to ascertain which of the two contains hydrogen. Explain how you would solve the problem.

7. Describe how you would prepare hydrogen, and explain your method?
Two bottles are given; one contains hydrogen and the other marsh-gas: how would you ascertain by experiments which of the two contains marsh-gas?

C.—CARBON.

1. Diamond, graphite, and charcoal are called modifications of the element carbon. Why do we assume that these substances represent different forms of the same element?

2. Explain why oxygen, hydrogen, nitrogen, and carbon are considered to be elements. Describe one experiment by which you could prove that diamond and graphite consist of the same element.

3. A solid substance is suspected to contain some compound of carbon. How would you ascertain, by experiment, whether such is the case?

4. Carbon is said to exist in three allotropic modifications. Describe fully why diamond, graphite, and charcoal are considered to be modifications of the element carbon.

5. A crystal is given to you, and you are requested to ascertain by a chemical experiment whether it is a diamond or a common rock crystal. Describe an experiment which will furnish the required information.

6. A splinter of a colourless transparent solid body is given to you. How would you ascertain (*a*) by physical tests; (*b*) by chemical tests whether this is glass or diamond?

7. What is the action of oxygen and of sulphur separately upon red-hot charcoal?

8. Describe fully why diamond, graphite, and charcoal are considered to be allotropic modifications of the element carbon.

D.—NITROGEN.

1. A piece of dry phosphorus is sealed up in a tube with atmospheric air and gently heated. What is the action of the phosphorus in this experiment? Describe the properties of the gas which is left.

2. Name the most important natural substances in which nitrogen is contained; and describe how you would prepare nitrogen. Enumerate the principal properties of nitrogen, and show how it may be distinguished from oxygen, hydrogen, and carbonic acid.

3. How can you obtain pure and dry nitrogen gas from atmospheric air?

4. How would you prepare nitrogen? What effect would an atmosphere of nitrogen produce on life and combustion?

E.—CHLORINE.

1. Describe the preparations and properties of gaseous and of liquid chlorine. What compounds does it form with oxygen and hydrogen respectively?

2. Describe the effects produced by chlorine on the following substances;—indigo solution, copper foil, powdered antimony, powdered charcoal, phosphorus, and sulphur.

3. Describe how you would prepare chlorine, and explain your process. Also give an outline of the chief chemical and physical properties of this element.

4. How would you prepare chlorine, and how do you explain your process? If one bottle contain chlorine gas, and another bromine vapour, how could you distinguish the two substances from each other? Why can chlorine not exist free in nature?

5. Explain the formation of chlorine from a mixture of black oxide of manganese and hydrochloric acid (hydric chloride).

What happens when a mixture of one volume of chlorine and two volumes of hydrogen is exposed to the sun's light? How will water act on the products of the reaction?

6. What action has chlorine gas, at ordinary temperatures, on the following substances: — carbon, hydrogen, phosphorus, water, sulphuretted hydrogen, and a solution of sulphurous acid?

7. Chlorine often acts as an oxidizing agent. How do you account for this? Describe some experiments in proof of your explanation?

8. Describe the preparation of chlorine, and explain your process. What happens when dry litmus-paper, an aqueous solution of litmus, a burning candle, and powder of copper, respectively, are introduced into chlorine gas?

See also A′ 3.

F.—BROMINE.

1. Two bottles are given, one contains vapour of bromine, and the other vapour of nitric peroxide N_2O_4, how would you ascertain which of the two contains bromine? Give a brief description of the characteristic properties of each substance.

See also G 2 and A′ 3

G.—IODINE.

1. Explain what occurs when a current of chlorine is passed through a solution of potassic iodide. How would you prove a brown liquid to be an aqueous solution of iodine?

2. Two aqueous solutions are given you, one contains free bromine only, the other free iodine only. Describe how you would prove the presence of the bromine in the one solution, and of the iodine in the other.

3. You are requested to ascertain whether a given black powder is composed of iodine or black-lead (graphite). How would you do so?

See also A′ 3.

H.—FLUORINE.

I.—SULPHUR.

1. What are the principal minerals containing sulphur? How is sulphur extracted? how purified? Describe the product of its combustion in air.

2. Describe the chief allotropic modifications of sulphur; and name the chief substances from which sulphur is obtained. How is sulphurous acid obtained? How much sulphur and how much oxygen are contained in one hundred grains of sulphurous acid?

3. Give a brief description of the allotropic modifications of sulphur, and of the preparation of each modification.

J.—PHOSPHORUS.

1. How is red phosphorus made from clear phosphorus? Describe the chief differences between the properties of the two varieties. Why is common phosphorus kept under water?

2. By what experiments could you prove that common phosphorus and red or amorphous phosphorus are allotropic modifications of the element phosphorus?

3. How can amorphous phosphorus be prepared from ordinary phosphorus? What are the differences in properties of these two bodies?

4. Give the formula of the body which is formed when you burn phosphorus in an excess of oxygen. How could you prove that common phosphorus and red phosphorus are allotropic modifications of the same element?

5. How would you prove that red phosphorus is an allotropic modification of the phosphorus which melts at 44° C.?

K.—SILICON.

L.—COMBINING PROPORTIONS BY WEIGHT AND BY VOLUME.

1. Give an outline of the theory by which the law of multiple proportions is explained.

2. Give the molecular weights of common salt, iodide of potassium, carbonic acid, and nitrate of silver. (The following atomic weights may be adopted:—chlorine, 35·5; sodium, 23; iodine, 127; potassium, 39; carbon, 12; oxygen, 16; nitrogen, 14; silver, 108.)

3. Illustrate the law of multiple proportions by a series of examples, including compounds of carbon with oxygen, carbon with hydrogen, sulphur with oxygen, and nitrogen with oxygen.

4. How much oxygen is contained in 10000 grains of potassic dichromate ($K_2Cr_2O_7$). How much oxygen is given off when the same quantity of salt is heated with an excess of oil of vitriol? $K=39$, $O=16$, $Cr=52·5$?

5. In what proportion by volume does oxygen combine with each of the following gases, viz.:—hydrogen, carbonic oxide, marsh gas, and olefiant gas?

6. How many grammes of oxygen and how many of hydrogen are required in order to prepare 500 grammes of water? How many litres will the hydrogen measure if each gramme measure 11·2 litres? How many litres will the oxygen measure, its density being 16 times as great as that of hydrogen?

7. How many volumes of their respective elements are contained in two volumes of each of the following gases?—hydrochloric acid, steam, and ammonia. Describe an apparatus for the decomposition of water by a galvanic current, and the results of the decomposition.

8. One hundred volumes of nitrogen are given. How many volumes of oxygen must be added in order to obtain a mixture of the same composition as pure atmospheric air?

9. What volume of oxygen is needed for the complete combustion of one gramme of carbon? (Sixteen grammes of oxygen measure 11·2 litres.)

10. What weight of oil of vitriol (H_2SO_4) must be decomposed for the evolution of one gramme of hydrogen?

11. How much carbon could be completely burned by a ton of air?

12. What weight of carbon is needed for the formation of 88 grammes of carbonic acid? What is the volume of this weight of acid at 0° C. and 30 inches barometric pressure?

13. It is asserted that one molecule of hydrochloric acid consists of one atom of chlorine and one atom of hydrogen; and one molecule of ammonia, of one atom of nitrogen and three atoms of hydrogen. What do we mean by an atom of nitrogen and an atom of hydrogen? Calculate the percentage composition of ammonia.

14. How much anhydrous phosphoric acid is formed by the combustion of one gramme of phosphorus ($P=31$)? How much pure air is needed for the production of this phosphoric acid?

15. How much pure air ought to be mixed with 100 measures of fire-damp (marsh gas) in a coal mine, in order to supply material for the complete combustion of marsh gas during explosion?

16. Describe by an equation what takes place when metallic zinc is acted upon by diluted hydrogen sulphate (sulphuric acid). Taking the atomic weight of zinc as 65, what weight of hydrogen would be evolved according to this process by the solution of one kilogramme of zinc?

17. What are the proportions, by weight, of the constituent elements of the following compounds:—marsh gas, olefiant gas, carbonic acid, and water?

18. A litre of carbonic acid is completely reduced to carbonic oxide by hot carbon. What volume of carbonic oxide is obtained? What volume of oxygen is needed for the complete combustion of this carbonic oxide?

19. The weight of 11.2 litres of hydrogen under normal conditions being 1 gramme, what are the weights of 100 litres of oxygen, carbonic oxide, carbonic acid, chlorine, and ammonia gases respectively under the same conditions?

20. Give the names and formulæ of the oxides of nitrogen, and calculate their percentage compositions.

21. Explain the action of oil of vitriol on common salt. What weight and what volume of hydrochloric acid gas (hydric chloride) could be obtained from 100 grammes of pure common salt (sodic chloride)?

Explain the action of aqueous hydrochloric acid on zinc, on red oxide of mercury (mercuric oxide), and on black oxide of manganese respectively.

22. How much oxygen do you require for the complete combustion of 10 cubic centimetres of marsh gas? How many cubic centimetres of each product of combustion would be formed?

23. Water is said to be composed of equivalent quantities of its two constituents, or of two atoms of hydrogen and one atom of oxygen. Why do you consider two atoms of hydrogen to be equivalent to one atom of oxygen?

24. How much phosphuretted hydrogen PH_3, by weight and by volume, would be furnished by 31 grammes of phosphorus, supposing all the phosphorus to be converted into the gas?

25. Explain what is meant by the term "molecular weight." One molecule of ammonia consisting of one atom of nitrogen and three atoms of hydrogen. What is the molecular weight of ammonia?

26. What bodies are formed by the combustion of sulphuretted hydrogen in air? How many cubic centimetres of pure oxygen are necessary for the combustion of 100 cubic centimetres of sulphuretted hydrogen?

27. Describe how you would prepare hydrochloric acid from common salt and sulphuric acid, and explain the reaction by means of symbols. How many volumes of chlorine and hydrogen are required for the formation of 100 cubic centimetres of hydrochloric acid? Explain the reactions which take place when an aqueous solution of hydrochloric acid is placed in contact with zinc, sodic hydrate, and black oxide of manganese, respectively.

28. Describe and explain the preparation of ammonia from ammonic chloride (chloride of ammonium) and slaked lime. The molecule of ammonia consisting of one atom of nitrogen and three atoms of hydrogen; what is the density of ammonia on the hydrogen scale? What happens when one volume of ammonia gas and three volumes of hydrochloric acid gas (hydric chloride) are mixed together?

29. Explain the meaning of the following equation:—

$$CH_4 + 2O_2 = CO_2 + 2H_2O$$

How many volumes of carbonic oxide and of oxygen, respectively, are required for the production of 75 c.cms. of carbonic acid (CO_2)?

30. A mixture of 10 cubic centimetres of oxygen, and 20 cubic centimetres of hydrogen, kept at the temperature of 120° C. in a eudiometer over mercury, is exposed to the action of an electric spark. How is the gaseous mixture affected by the experiment?

31. Express by an equation the reactions which occur when zinc is thrown into diluted hydrochloric and sulphuric acids respectively (hydric chloride; hydric sulphate). How much hydrogen could you obtain by the solution of 100 grammes of zinc? How much water could be obtained by the combustion of this hydrogen?

[Atomic weight of zinc = 65·2.]

32. The action of sodium on water is represented by the equation

$$Na_2 + 2H_2O = 2NaHO + H_2,$$

How much water is required to take part in this reaction in order to obtain 22·38 litres of hydrogen at 0° C. and 760 mm. pressure?

[*Remainder of question under "Chemical Peculiarities of Natural Water."*]

33. Supposing the air to contain 23 per cent. of oxygen by weight, how many grammes of it must be supplied in order to burn completely (*a*) 10 grammes of carbon, (*b*) 10 grammes of sulphur, (*c*) 10 grammes of phosphorus? C = 12, S = 32, P = 31.

34. A gaseous mixture consisting of 100 volumes of carbonic oxide and 150 volumes of oxygen is confined over mercury; an electric spark is passed through the mixture, and a ball of caustic potash is then brought into the gas. Describe the chemical changes which occur, and state what volume (if any) of gas remains at the end of the operation.

35. Fifty cubic centimetres of oxygen and 150 cubic centimetres of hydrogen are placed in a dry eudiometer at a temperature of 120° C., and under the normal atmospheric pressure; an electric spark is then passed through the mixture. What will be the volume after the explosion, the temperature and pressure being supposed to remain as they were?

36. If 126 grammes of nitric acid (hydric nitrate) were neutralised with ammonia gas, what weight and what properties would the new compound have?

37. If two volumes of marsh gas, weighing 16 grammes, be burnt in excess of air, how many volumes of carbon dioxide (carbonic acid gas) are produced; also, what is the weight of the other compound formed at the same time?

38. Describe an experiment to show that hydrochloric acid gas is composed of equal volumes of its constituents, united without condensation. What is the weight of 11·2 litres of this compound? (Cl = 35·5.)

39. Calculate the percentage composition of nitric acid. (N = 14, O = 16, H = 1.)

40. How many volumes of oxygen are needed completely to burn 20 volumes of olefiant gas, and what is the volume of carbon dioxide (carbonic acid gas) produced?

41. If air contain 23 per cent. of its weight of oxygen, how many pounds of carbon must be burnt in order to remove all the oxygen from 500 lbs. weight of air?

42. Calculate the density of nitrous oxide (N_2O) at 0° C. and 760 mm.

43. Six grains of carbon and 22 grains of oxygen are heated to redness in a hermetically closed tube. What substance, and what amount of it is produced? Why is carbon dioxide commonly called carbonic acid? The amount of carbonic acid in our atmosphere does not appear to increase. How do you account for this?

44. Calculate the per centage composition of saltpetre (KNO_3, K = 39, N = 14, O = 16).

A gas is composed of 92·3 parts of carbon and 7·7 parts of hydrogen. How many atoms of hydrogen are united in this gas to two atoms of carbon?

45. How many c.c. of oxygen gas are required for the complete combustion of 200 c.c. of olefiant gas? What products are formed, and how many c.c. of each do you obtain?

46. Explain the meaning of the equation :—

$$2\ KI + Cl_2 = 2\ KCl + I_2.$$

The combustion of hydric sulphide in air is represented by the equation :— $H_2S + O_3 = H_2O + SO_2$.

How much sulphurous acid and how much water can be formed from 100 grains of hydric sulphide? [$H=1$, $S=32$, $O=16$.]

47. If you heat common salt with hydric sulphate (H_2SO_4) hydric chloride (HCl) is given off. How many cubic centimetres of hydric chloride at 0°C. and 760 mm. pressure could you liberate from 1000 grammes of sodic chloride?

48. Write the names of the following compounds :—

CO; CO_2; N_2O; N_2O_3; N_2O_5; CH_4; C_2H_4; SO_2; SO_3 and H_2S.

If the density of hydrogen is 1, the molecular weight 2, and the molecular weight of ammonia 17, find the density of ammonia.

How many grains of carbonic acid (CO_2) will combine with 100 grains of calcic oxide (CaO) to form calcic carbonate (CaO, CO_2)? $C=12$ $O=16$ $Ca=40$.

M.—GENERAL NATURE OF ACIDS, BASES, AND SALTS.*

1. Describe experiments by which you could prove that silica must be classed among acids.

2. Describe experiments by which you would endeavour to ascertain whether a given substance (dissolved in water) is an acid, a base, or a salt. Give an example of a body belonging to each of the above named classes, and enumerate those properties of each body which you consider to afford the best proof that it belongs to the class to which you assign it.

3. Two liquids are given, one containing an acid and the other a base. Describe the experiments you would perform in order to ascertain which of the two liquids contains the acid.

4. Two oxides are given to you, one an acid, the other a base. Explain how you would determine which of the two is the acid.

5. Describe the experiments you would perform in order to decide whether the oxide formed by the combustion of phosphorus in oxygen is an acid or a base.

6. Silica has no taste, and does not act on blue litmus. Why do we call this substance silicic acid?

See also Z 2 and 3.

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* It is usual now to distinguish between *acids* and *anhydrides*, thus, CO_2 is regarded as carbonic anhydride, while H_2CO_3 is carbonic acid. As these questions extend over a period of many years, it is difficult to say, in some cases, *whether the Examiner* means by an acid the anhydride, or the acid in its more *modern acceptation.*

N.—SYMBOLS AND NOMENCLATURE.

1. Write in symbols the following compounds :—water ; sulphuric acid ; nitric acid ; nitrous oxide ; sulphuretted hydrogen.

2. Explain the following chemical reactions :—(*a*) The decomposition of steam by red hot iron ; (*b*) the decomposition of water by potassium in presence and absence of atmospheric air ; (*c*) the formation of hydrochloric acid and sulphate of soda from common salt and sulphuric acid ; (*d*) the action of chlorine on sulphuretted hydrogen.

3. Explain fully the meaning of the following symbols :—
O_2 ; H_2 ; Cl_2 ; Br_2 ; I_2 ; C; N_2 ; S; P; CO_2 ; SO_3 ; H_2O, and NH_3.

4. Give the symbols of the following elements and compounds :—hydrogen, nitrogen, nitrous acid, carbon, marsh gas, chlorine, bromine, phosphorus, phosphoric acid, and silicic acid.

5. Give the formulæ of the following substances :—water, ammonia, silica, carbonic acid, sulphuric acid, marsh gas and phosphuretted hydrogen.

6. Express in symbols what takes place (*a*) when sulphuric acid and chloride of sodium are heated together ; (*b*) when sulphuric acid, chloride of sodium, and binoxide of manganese are heated together ; (*c*) when nitrite of ammonia and nitrate of ammonia are each subjected to heat.

7. What is the difference in composition between a sulphite and a sulphate ; between a nitrite and a nitrate ; and between nitrous oxide and nitric oxide ?

8. Express by equations the reactions which occur when sulphuric acid is heated together with common salt, with sal-ammoniac, with nitre and with copper respectively.

9. What is the composition of the following substances :—Air, silica, marble, ammonia, marsh gas, and black lead, or plumbago ? Give the names of the substances represented by the following formulæ :—CO ; NO ; SO_2 ; N_2O_3 ; PH_3 and NH_4Cl.

O. — THE ATMOSPHERE — ITS CONSTITUTION, EFFECTS OF ANIMAL AND VEGETABLE LIFE UPON ITS COMPOSITION.

1. How much oxygen is contained in 60 cubic inches of air ? What are the other constituents ?

2. Why is atmospheric air supposed to be a mechanical mixture and not a chemical compound of oxygen and nitrogen ?

3. Describe the chief process by which oxygen is being removed from the atmosphere. How is it that the ratio of oxygen to nitrogen is nevertheless practically invariable?

4. Explain how you would prove the presence of water, carbonic acid, oxygen, and nitrogen, in atmospheric air.

5. Name the constituents of the atmosphere. How did Lavoisier show the presence of oxygen in air?

6. Name the two chief constituents of our atmosphere; state in what proportions they occur in it; and give their respective symbols. Why is air considered to be a mechanical mixture and not a chemical compound of these constituents?

7. Describe the experiment by which Lavoisier proved air to consist of oxygen and nitrogen.

How many cubic centimetres of oxygen are contained in 100 cubic centimetres of air? How many cubic centimetres of hydrogen would be burnt by this quantity of oxygen?

8. Our atmosphere is said to take part in the processes of combustion, of respiration, and of the growth and decay of plants. Explain how, and by means of which of its constituents, the air acts in each of these processes.

9. Name the principal constituents of our atmosphere. How is the composition of the air affected by its passage over a long layer of red hot charcoal?

10. The ancients supposed air to be one of the elements. Describe properties of air which cause it no longer to be regarded as an element.

11. Explain how the composition of the atmosphere is influenced by animal life. What are the chief conditions on which the amount of aqueous vapour in the atmosphere depends?

12. The ancients used to consider air to be one of the elements. How would you prove experimentally that air is not a single substance, but a mixture of oxygen and nitrogen?

13. A small box, containing a live guinea-pig, is placed on the pan of a delicate balance, and the instrument then exactly equipoised. If the whole be now allowed to remain at rest, it will soon be seen that a distinct diminution of the weight of the box and its contents occurs. Explain this fact.

14. The ancients regarded air as an element. Prove by experiments that it consists mainly of oxygen and nitrogen.

P.—COMBUSTION.

STRUCTURE AND PROPERTIES OF FLAME. NATURE AND COMPOSITION OF ORDINARY FUEL.

1. Explain why a candle cannot long continue to burn in a closed bottle. How is the composition of dry air affected by its passage over red hot iron or copper? How much air is needed for the complete combustion of 6 grains of pure carbon?

2. Explain fully why the flame of a common gas-light is brighter than the flame from a Bunsen burner. (A mixture of air and gas is burnt in the latter case.)

3. Describe the products which are formed during the combustion of coal-gas; and explain what means you would adopt for their detection. Why does olefiant gas burn with a brighter flame than hydrogen?

4. Describe the structure of the flame of a common candle; and explain why the flame loses its brightness when a current of common air is blown into it.

5. What compounds can be formed by the combustion of the following substances in a limited and in an excessive quantity of air; and what are their respective formulæ:—sulphur, phosphorus, hydrogen, and carbon?

6. Describe the structure of the flame of a common candle, and explain why carbon is set free by the combustion in the interior, but not on the surface of the flame.

7. What bodies are produced by the combustion of ordinary illuminating gas? Why does the flame of an ordinary moderator lamp appear brighter with than without a chimney glass? Why is the light given out by a flame diminished when a current of air is blown into it?

8. How would you show that air is necessary for the maintenance of ordinary combustion? How does air act on a burning substance? How could you show that the product of combustion of phosphorus in oxygen consists of phosphorus and oxygen?

9. If you place the chimney-glass over the flame of a reading lamp the flame increases in brightness;—why does it do so? If you blow a current of air into the flame of an ordinary candle, the flame appears less bright than it did before the introduction of the air. Explain why this is the case.

10. Three parts can be distinguished in the flame of a candle: (*a*) a dark part in the interior; (*b*) a luminous cone around (*a*); and (*c*) a thin almost non-luminous envelope around (*b*).

Explain this structure of the flame, and describe how you would support your explanation by experiments.

11. If you place a burning candle into a closed bottle the flame will soon be extinguished. Why does the candle not continue to burn? How is the composition of the air affected by the flame?

Q.—WATER.

CHEMICAL PECULIARITIES OF NATURAL WATERS, SUCH AS RAIN-WATER, RIVER-WATER, SPRING-WATER, SEA-WATER.

1. Describe an arrangement for decomposing water by the galvanic current; and state the proportions by volume and by weight in which the constituents are given off.

2. Describe properties of oxygen, hydrogen, and water, which justify the conclusion that water is not an elementary substance.

3. In what respects does rain-water differ from sea-water? Enumerate the most common constituents of spring-water. How is pure water obtained from spring-water? and how would you ascertain whether a given sample of spring-water contains sulphuretted hydrogen?

4. During the Abyssinian expedition, drinkable water had to be prepared from sea-water. Show how this can be done. Enumerate the principal constituents of sea-water.

5. What is meant by the term "hardness," as applied to water? How would you ascertain whether a particular sample of water is hard or not?

6. Water is said to be a compound of hydrogen and oxygen. Describe experiments in proof of this view, and explain why hydrogen and oxygen are called elements.

7. The hard water of our chalk districts is rendered soft by the addition of lime-water. Explain fully why lime-water is able to produce this result.

8. The well-water at Canterbury is rendered soft by addition of an aqueous solution of lime. Explain why lime is able to render some kinds of hard water soft.

9. You boil common well-water for a few minutes and observe the separation of a white precipitate. How do you explain the formation of the precipitate? How would you test your explanation by experiment?

10. Sketch and describe an apparatus by which sea-water may be rendered fit for drinking purposes. How can a hard water be converted into a soft one?

11. Three samples of water are given you; one is a hard water, another a soft water, and the third a sea-water. What chemical experiments would enable you to discriminate between them?

12. Describe the methods and give sketches of the apparatus you would use to determine the composition of water (1) by volume, (2) by weight.

13. Explain how it is that fish can obtain sufficient oxygen for their respiration. What experiment can you suggest for the purpose *of proving the correctness* of your explanation?

14. How would you prove by means of experiments that water is a compound of hydrogen and oxygen?

15. The spring-water of our chalk districts is much harder than the river-water of the same localities; why is this the case?

At Canterbury the water is rendered soft by the addition of a certain quantity of lime-water; explain the process.

R.—CARBONIC ACID, CARBONIC OXIDE.

1. What is the process which takes place at the lower part of a charcoal fire, through which moist air ascends? What changes do the resulting gases undergo on passing through the upper portion of the fire?

2. How would you prove that carbonic acid consists of carbon and oxygen? How is carbonic acid usually prepared? How do you distinguish carbonic acid from nitrogen?

3. How is pure carbonic acid prepared? How much heavier than hydrogen is it?

4. Describe how you would prepare carbonic acid from chalk, and explain your process by means of symbols. How would you test whether the air in a well consists of ordinary air or of carbonic acid? By what means would you detect carbonic acid in spring water?

5. A current of pure air passes through a bright coke fire. What gases are contained in the air beyond the fire? Give a short description of each of them.

6. Enumerate the chief native sources of carbonic acid: and mention the causes which tend to keep down the amount of this gas in our atmosphere.

7. Describe an experiment by which you would prepare carbonic oxide gas from carbonic acid.

8. Two bottles, one containing carbonic oxide, and the other anhydrous carbonic acid, are given you to determine the nature of the gas in each bottle. Describe the experiment you would perform for this purpose. By what process is carbonic acid generated in nature?

9. What gaseous products will be formed by the complete combustion of common coal in an ordinary fire?

The air of the *Grotto del Cane*, near Naples, is said to be composed of nearly pure carbonic acid. Describe experiments you would perform in order to test the accuracy of the statement.

10. The gas which accumulates in the *Grotto del Cane*, near Naples, is said to be carbonic acid. Describe how you would test by experiments the correctness of the assertion.

11. Explain the action of hydric chloride (HCl) on calcic carbonate. If you pass carbonic acid over a layer of red-hot charcoal, it becomes converted into a combustible gas. Explain the reaction which takes place between carbonic acid and hot charcoal.

S.—OXIDES AND ACIDS OF NITROGEN.

1. Give the names and chemical formulæ of the substances formed by the action of hydrogen nitrate (nitric acid) upon metallic copper. What happens when the gas produced in this reaction comes in contact with the air?

2. A given sample of gas is found to have the property of kindling a glowing splint of wood. Enumerate the reactions by which you would decide whether it consists of oxygen or nitrous oxide.

3. Why do you call oxygen, hydrogen, and carbon chemical elements? Describe the properties by which you would distinguish nitrous oxide (laughing gas) from a mechanical mixture of two volumes of nitrogen and one volume of oxygen.

4. Explain, by means of symbols, the formation of nitric acid from saltpetre and common sulphuric acid. You prepare hydrogen by the action of zinc upon dilute sulphuric acid; why cannot hydrogen be procured by the action of zinc upon dilute nitric acid? Explain what happens when concentrated nitric acid is placed in contact with a solution of potassic hydrate.

5. Describe how you would prepare nitrous oxide. How would you distinguish this gas from oxygen?

6. Explain, by means of symbols, the decomposition which takes place when hydric sulphate is mixed with saltpetre. What happens when hydric nitrate is added to a solution of potassic hydrate? What is the difference between a nitrate and a nitrite?

7. Give the formulæ of potassic nitrate and potassic nitrite.
Explain the reaction which takes place when you add hydric sulphate to potassic nitrate.
What is the difference between a sulphate and a sulphite?

T.—AMMONIA.

1. What is ammonia? How is it obtained? Give its composition by weight and by volume.

2. Describe the preparation of ammonia from ammonic chloride (sal-ammoniac); and explain your proofs by means of symbols. What volume of hydrochloric acid gas is needed in order to condense a cubic inch of ammonia?

3. How would you obtain evidence of the presence, in a given solution, of ammonia whether free or combined?

4. Explain, by an equation, the process of making ammonia by the action of slaked lime upon sal-ammoniac; and describe the properties of the gas.

5. Ammonia gas is passed (*a*) into water, (*b*) into dilute sulphuric acid. Describe in detail what takes place. How can the gas be again obtained from both these solutions?

6. Describe how you would illustrate experimentally the basic properties of ammonia.

7. Describe how you would prove that ammonia is a compound of hydrogen and nitrogen.

U.—OLEFIANT GAS, MARSH GAS.

1. How is olefiant gas prepared? What is its composition, and how is this ascertained? Mention the distinguishing characteristics of this compound.

2. How is marsh gas prepared? If 100 volumes of this gas be exploded with 400 volumes of oxygen, what bulk of gas will remain, and of what will it consist?

3. How is olefiant gas prepared? By what means could you convince yourself that this gas contains twice as much carbon as an equal bulk of marsh gas does?

V.—SULPHUROUS AND SULPHURIC ACIDS.

1 A sample of vinegar is supposed to be adulterated with sulphuric acid. How would you ascertain the presence of sulphuric acid in vinegar?

2. How would you prepare sulphurous acid gas? Describe and explain the reaction by which you would identify it.

3. How is sulphuric acid (oil of vitriol) made? Explain the chemical changes which take place in the process.

4. What are the tests you would employ in order to detect the presence of a dissolved sulphate, chloride, sulphide, and nitrate?

5. What substance do you obtain when a piece of sulphur is burnt in oxygen? How can this substance be converted into common sulphuric acid? How would you ascertain whether a specimen of an acid consisted of sulphuric or of nitric acid?

6. How are the compounds of sulphur and oxygen formed? Give their formulæ and properties. Describe their action upon water, and upon a solution of carbonate of soda.

7. Write down the formulæ (1) of the oxides of sulphur, (2) of the substances formed when they are brought in contact with water, (3) of the neutral and acid sulphate and sulphite of potassium. Give tests for distinguishing between soluble sulphites and sulphates.

W.—SULPHURETTED HYDROGEN.

1. How would you prepare sulphuretted hydrogen gas? What is formed when the gas is burnt in air?

2. A specimen of spring water is supposed to contain sulphuretted hydrogen (hydric sulphide). How would you ascertain whether any sulphuretted hydrogen is present.

3. Explain, by means of symbols, the formation of sulphuretted hydrogen from ferrous sulphide (Fe S) and hydric sulphate (sulphuric acid H_2SO_4). How do you prove that sulphuretted hydrogen is a compound of sulphur and hydrogen? How does sulphuretted hydrogen act on a solution of litharge (PbO) in hydric nitrate (HNO_3)?

4. How would you show that sulphuretted hydrogen is a compound of sulphur and hydrogen?

X.—HYDROCHLORIC ACID.

1. What is the composition by weight and volume of hydrochloric acid? How is it obtained? Mention some of its chief chemical properties.

2. Explain, by means of symbols, the preparation of hydrochloric acid from common salt and sulphuric acid. How many volumes of chlorine and hydrogen are required for the preparation of two volumes of hydrochloric acid? How does water act on hydrochloric acid gas?

3. Describe the preparation of aqueous hydrochloric acid; and explain the process by an equation. How would you distinguish it from an aqueous solution of nitric acid?

4. A gas is found by analysis to consist of equal volumes of chlorine and hydrogen. Describe fully how you would find by experiment whether the gas is a mechanical mixture or a chemical combination of the two elements.

5. Give several reactions by which hydrochloric acid may be prepared. What are the properties of this gas? and how may it be obtained in the liquid state?

6. How would you prove that hydrochloric acid gas contains chlorine and hydrogen?

7. How would you test an aqueous solution for hydric chloride (HCl), hydric sulphate (H_2SO_4)) and ammonia (NH_3) respectively?

Y.—PHOSPHORIC ACID AND PHOSPHURETTED HYDROGEN.

1. What substance is formed when a piece of dry phosphorus is burnt in excess of dry air? Give the formula of the phosphoric compound produced, and explain how it is acted upon by boiling water.

2. Explain the chemical reaction which takes place when phosphorus and milk of lime are boiled together. How do you account for ordinary phosphuretted hydrogen losing its property of spontaneous inflammability when kept for some time at a low temperature?

Z.—SILICA.

1. Describe how you would render silica soluble in aqueous hydrochloric acid, and how the soluble modification of this substance can be converted into the insoluble form?

2. Flint is said to be composed of silica, which, although it has no sour or acid taste, is also called silicic acid. Why is it so called?

3. How could you prove that the constituent of flint has properties similar to other acids; and how can this substance be obtained dissolved in water?

A′.—NOT CLASSED UNDER PREVIOUS HEADS.

1. What is the difference between a mechanical mixture and a chemical combination of two elements, A and B? Illustrate your answer by two or three examples.

2. Describe experiments by which you would distinguish a mechanical mixture of oxygen and hydrogen from the common compound of those elements.

3. A white salt is known to be either chloride, bromide, or iodide of potassium. How would you ascertain with certainty which of these substances it is?

4. Two powders are given you, one is a mechanical mixture, the other a chemical combination of sulphur and iron. In what respects would the two powders differ, and by what chemical reactions could you distinguish the one from the other?

5. A solution contains either carbonate of soda, chloride of sodium, or sulphide of sodium. How would you ascertain which of the three is present?

6. I pour dilute sulphuric acid (1) upon sulph*ide* of iron, and (2) upon sulph*ite* of sodium. Give equations showing the reaction which takes place in each case.

7. A given powder is composed of 32 gr. of sulphur and 56 gr. of iron. How would you ascertain whether the powder is a mechanical mixture or a chemical combination of the two elements?

A 1-20

ANSWERS.

A.—COMPOSITION AND RESOLUTION OF STATICAL FORCES.

1. The diagonal through A of which AB and AC are sides. Angle of 25°.

2. W along CW and W′ along CB and CA. If not equal the the two weights W′ and the cord would move in the direction of the heavier weight.

3. The moments of the forces AB and CD round E are equal.

4. The tension AP of the cord, the weight AR of the plummet, and the force AQ of the current, act upon the plummet, and are in equilibrium.

5. Explain by the polygon of forces, or by use of the parallelogram of forces three times.

6. Use a parallelogram, the diagonal of which represents the force of the current.

7. The attached weight and zero.

8. Horizontal force = F, inclined force = $\sqrt{2}$ F.

9. Produce the direction of one of the forces so that both act to, or from, the point. 200 lbs. towards the centre of the circle.

10. Tension of horizontal cord = 13·86 lbs., of inclined cord = 26·72 lbs.

11. If the two forces act in the same order, the third in the opposite, 17·32 lbs.

13. The effect of the force in turning a body round that point. The force multiplied by its perpendicular distance from the point. The algebraic sum of the moments of the forces must equal zero.

14. Their resultants are 14·2, 12·1, and 9·5 nearly.

17. 25 acting vertically upwards, 27·73 inclined downwards and to the right.

19. Two forces of 7 and 7 inclined at 120° have resultant 7 inclined at 60° to either component.

20. The ratio of component parallel to bank to that of the whole force becomes greater as the rope is lengthened. In case of tug the force is not resolved.

22. The resultant acts in the direction of the hypothenuse of a right-angled triangle, having a horizontal side of length 1 and a vertical side of length 2. Pressure on upper block is $\sqrt{5}$, P.

23. See A4.

25. Total force = 2·7, vertical component = 2·34 nearly.

27. Moments of weights acting through centres of gravity of AC, BC round point C should be equal; or common centre of gravity of ACB should be in vertical through C.

28. Weight of beam acting vertically downwards through its middle point, reaction of wall acting at B at right angles to it, reaction of bowl acting at A at right angles to it, are the only acting forces. These must pass through one point.

29. P = lesser force = 8 lbs. Q = 9.

30. Three forces act:—reaction of arc at B and C passing through centre of circle, and weight of arc which must also pass through centre of circle, and therefore through centre of arc.

31. Three forces act:—weight of beam through middle point, reaction of wall at A at right-angles to it, and reaction of beam at C at right-angles to it; these must pass through one point.

32. Polygon of forces.

34. 10 lbs.

36. Vertical through centre of gravity must pass through point of support.

37. Neglect the reaction of the plane. 2 kilogs. parallel to plane support 4 kilogs., the remaining kilog. will be supported by $\frac{1}{\sqrt{3}}$ kilog. Thus $P = \frac{1}{\sqrt{3}}$ kilog.

39. Horizontal forces acting on ladder are 60 and F $\therefore$ F = 60. Vertical forces are W, R, and 40 $\therefore W = R + 40$. Take moments round foot of ladder, thus $\frac{1}{2} W = 60 \sqrt{3} + 40 \therefore W = 120 \sqrt{3} + 80$ and $R = 120 \sqrt{3} + 40$.

40. See A13.

41. 16 lbs. From a point 8 in. beyond end of bar.

43. $5\frac{1}{7}$, $13\frac{1}{7}$, $29\frac{1}{7}$, $61\frac{1}{7}$ inches.

44. 8 lbs. and 6 lbs.

47. Resultant of all forces must pass through the point.

48. Resultant is parallel to diagonal of parallelogram AD, AC, and *magnitude* is same as AB.

B.—SIMPLE MACHINES.

1. 1 to 754 nearly.

2. 120 lbs.

3. Use it as a moveable pulley.

4. 2240 lbs. = 1 ton; 2400 lbs.

5. First system with 2 pulleys, or second system with 4 strings at lower block.

6. P : W :: height : length. Neglect friction, portion parallel to plane = W; portion hanging vertically = P; portion which is horizontal has no effect.

7. 1 to 754 nearly. Screw press, lathe, planing machine, &c.

8. 300 lbs.

9. Third system with three pulleys. P : W :: 1 : 7.

10. 8¼ inches from heavier weight. 40 oz.

11. If x and y are the apparent weights $\therefore$ $W = \sqrt{xy}$.

12. Circumference of screw = base of plane, pitch of screw = height of plane, power acts parallel to base of plane.

13. First system, the act of nailing the cord to one pulley fixes it, and so causes the system to act as one of three moveable pulleys, P : W :: 1 : 8; 9 P.

14. P : W :: 1 : 5. R = 5·57 P applied at the fulcrum.

15. $W = (2^n - 1) P$. $W = (2^n - 1) P + (2^{n-1} - 1) w_1 + (2^{n-2} - 1) w_2 + (2^{n-3} - 1) w_3 + \ldots\ldots.$

16. $3 \sqrt{3}$ lbs.

17. *a* 50 lbs., 25 in.; 40 lbs. 7½ in. *b*. 62 lbs., 31 in., 72 lbs., 13½ in. No change as regards distance between P and W, but the pressure on the fulcrum would be 9 lbs. more in each case.

18. 15 lbs. 13 lbs.

19. Take moments round foot, tension = 11¼ lbs. Combine tension and weight by parallelogram of forces, pressure = 27·4 lbs.

20. 3 lbs. P × distance moved over = W × distance moved over; or work done by P = work done upon W.

21. Principle of lever.

22. Force applied to cart acts at axle, but if applied at top of wheel, the pressure on axle = 2 P.

23. Vertically upwards when R = O; at an angle of 60° to the plane when $R = 6\sqrt{3}$.

24. Second system, 10 strings at lower block. Distance through which P acts = 80 ft. = 8 × 10.

25. 7 ft. 7⅓ in. from one end.

26. True weight = 6 lbs. thus arms are as 9 : 6 or 6 : 4, that is 3 : 2.

27. P : W :: 1 : 7. ½ inch from A towards B.

28. First system with 3 moveable pulleys. Neglecting friction and the weight of the pulleys, the mechanical advantage would be 8, but as these cannot be eliminated, practically the mechanical advantage would be less than 8.

31. See answer to B20.

32. Height = 3, base = 4, and length = 5 ∴ R = 5 lbs.

34. 24·494.

C.—CENTRE OF GRAVITY.

1. To keep the vertical through his centre of gravity between his feet. No.

2. The moment of the weight round the point of support becomes zero, only when its line of action passes through that point.

3. The scale pan moves till its centre of gravity is vertically beneath its point of support.

4. Just above 45°.

5. 9 lbs.

6. 3 inches from centre of heavier sphere.

7. Its middle point.

8. The other extremity of the diameter through the point to which the string is attached.

9. AC and BD cut one another at G, the centre of gravity. Join EG and produce it to cut BC at F. F is the required point.

10. Two-fifteenths of height of equilateral triangle from centre of hexagon.

11. 3·26 inches from the top.

12. At a point in the axis of wider cylinder $\frac{11}{13}$ in. from junction.

13. 3·2 in. from 5 oz.

13a. Find centre of gravity of 2 and 5, and of 3 and 4, then of the two 7 lbs. thus obtained, $\frac{1}{7}$ side of square from its centre. Position of centre of gravity would not change.

14. Its centre of gravity will be raised.

15. The centre of gravity of the triangle.

16. The geometrical centre of the hemisphere.

17. One twenty-seventh of line, joining middle point of base to vertex, from the base.

21. $14\frac{1}{11}$ inches from free end of 8 oz. tube.

22. 4·392 inches

23. $13\frac{14}{135}$ inches.

24. $\frac{1}{3}\sqrt{3}$ in.

D.—GENERAL LAWS OF MOTION.

1. 936 feet.

2. The gun and bullet are forced in opposite directions, with the same momentum.

3. It moves with uniform velocity in a straight line.

6. If a body of mass m lbs. be acted upon by a constant force of P lbs. or Pg units $s=\frac{1}{2}\frac{Pg}{m}t^2$. 4 feet per second.

7. Acceleration = increase of velocity per unit of time in unit of time, it varies directly as the force and inversely as the mass moved. 2·5 feet.

8. As 5 is to 1.

10. Mass moved = 10 oz. moving force = weight of 4 oz. = $4g$ $\therefore f = \frac{4g}{10} = 12{\cdot}8$ ft. per sec.

12. $f' = \frac{2}{3}f$.

13. The forces must be in equilibrium, but must be started by a momentary force.

14. 40 miles per hour ; $\frac{4}{5}$ mile.

15. P : W :: 11 : 1080.

17. 2 seconds nearly.

18. A body could fall 5 feet in ·56 seconds ∴ horizontal velocity = 715 feet per sec.

D 19–40

19. Carriage alone would have an acceleration $= \frac{g}{5} = 6{\cdot}4$ feet per sec. down the plane, the rope must neutralize this as well as cause an acceleration of 3 ft. per sec. up the plane, it therefore actually causes an acceleration $f = 9{\cdot}4$ ft. per sec. The tension $T = \frac{mf}{g} = 2{\cdot}35$ tons.

20. $f = \frac{g}{5} = \frac{32.2}{5} \therefore s = 181{\cdot}125$ ft.

21. 225 feet. In $2\frac{1}{2}$ secs. and in 5 secs.

22. Nothing, since the weight causes the mass to fall with you.

23. $f = \frac{g}{16} \therefore$ weights are $3\frac{3}{4}$ oz. and $4\frac{1}{4}$ oz.

24. The feather has the same horizontal velocity as the balloon, it therefore appears to fall vertically.

25. Stone has same velocity as surface, and therefore, a greater velocity than interior; it strikes the tube on the east side.

26. She must be steered 30° up stream, and travels over $\frac{2}{\sqrt{3}}$ miles in 8·66 minutes.

29. Horizontal distance = 4·4 ft.; vertical distance = ·16 ft.

30. Air, with the surface of the earth, has a smaller velocity in higher latitudes, and, therefore, appears to be left behind on approaching the equator, *i.e.* forms a N.E. wind.

31. $g = 980$ centimetres per second.

32. A body free to move under the action of its own weight, gains in each second of its motion an extra velocity of 32 feet per second. $g = 78545{\cdot}45$ miles per hour.

33. In first case, stone falls with the chamber. In the second case, while the velocity of the chamber is V, that of the stone will be $V + gt$, it therefore strikes the floor of the chamber.

34. Unit of force : weight of one pound :: 1 : g :: 1 : 32.

36. Accelerating force = constant force *e.g.* weight, which is independent of the time; the acceleration produced by the force varies as the square of the unit of time. Thus the force = F, the acceleration $= \frac{f}{3600}$ when 1 sec. is the unit of time.

37. $f = \frac{g}{32} = 1$. Tension = 15·98 oz.

38. The body moving uniformly, moves over 12 ft. in 4 secs., the two bodies are then 20 ft. apart, the other must have moved over 16 ft. Thus $f = 2$ ft. per sec.

40. $f = 4$ centimetres per second, thus other mass = 492 *grammes.*

41. 393 oz.

42. Wt. of 1 lb. $= g$ (lb. ft. sec.) as units.
$= 16g$ (oz. ft. sec) ,,
$= 16 \times 12g$ (oz. in. sec.) ,,

∴ given unit of force : weight of 1 lb. :: 1 : 192g :: 1 : 6144.

44. That force which acting on a mass of 1 lb. gives it a velocity of one foot per second in one second.

45. 12·8 oz.

46. $f = 3·2$, $s = 40$.

E.—LAW OF THE MOTION OF FALLING BODIES.

1. 256 feet. 64 feet per second.

2. 6·25 seconds. With the same force the second arrow has double the velocity, and will return in 12·5 seconds.

3. Prove formula $s = \frac{1}{2}ft^2$.

4. None, since he already has the same motion as the carriage.

6. $v = 32$ ft. per sec., thus $V = 16$ ft. per second and space $=$ 32 ft.

7. 22·5 feet.

8. 144 feet.

9. 402·5 feet. 177·1 feet.

10. Velocity $=$ 68·6 feet, height $=$ 308·7 feet. ($g = 32·2$.)

11. If $h =$ height ∴ $V = \sqrt{2gh}$, $t = \sqrt{\frac{h}{2g}}$ and they pass at a height $= \frac{3h}{4}$

12. The particle falls in $3\frac{1}{3}$ secs., is carried horizontally 10 feet, and thus strikes the ground $179\frac{1}{3}$ feet from its starting point. ($g = 32·2$.)

13. $f = 16·1$ thus it rolls 8·05 feet up the plane; 120·75 feet down the plane.

14. Space $=$ 864 feet, velocity $=$ 464 feet per sec.

15. Initial velocity $=$ 136 feet per sec.; rises 88 feet.

16. $V = 96$, therefore height above ground $=$ 80 feet.

17. Show the path in a diagram by finding the position of the stone at end of 1st, 2nd, 3rd, &c., seconds. At the end of two seconds, it would, if not acted upon by gravity, have travelled over 256 feet in a straight line inclined at 45°, but during that time gravity causes it to fall 64 feet.

19. 16 feet, 32 feet. $s = Vt + \frac{1}{2} ft^2$ and $v = V + ft$ $\therefore s = \times \frac{V + v}{2} t$.

20. (1) $v = 980$, energy = 49000 gramme-centimetres, (2) $v = 490$, energy = 12250 gramme-centimetres, (3) $v = 0$, energy = 0.

21. 1200 feet per second.

23. 3¾ seconds, 112½ feet,

24. 12742·1 cms.

25. 5·47 seconds. 87·632 ft.

26. 1·488 feet nearly.

F.—HYDROSTATICS, HYDRAULICS, AND PNEUMATICS.

1. The mercury will rise in the barometer tube, to balance increase of pressure on cistern.

2. The cork is forced into the bottle filled with air, because the pressure upon it increasing with the depth, the volume of the air becomes smaller. If the bottle be filled with water, which does not sensibly decrease in volume under moderate pressures, the cork will not be forced in.

3. 2 atmospheres = a height of 60 inches of mercury = nearly 30 lbs. on the square inch.

4. 97 feet.

6. Pressure = 240·3 inches of mercury; volume = 37·46 cubic inches

7. 34 feet.

8. Pressure = weight of 80 cubic feet of water = 80000 oz.

9. Pressure on one side = weight of 300 cubic inches of water = 173·61 oz.

10. Volume varies inversely as the pressure.

11. When the vessel is other than a cylinder or prism whose sides are at right angles to its base.

12. Pressure varies directly, as the weight of a constant volume of gas. As 7 is to 4.

14. The specific gravity of the balloon and contents, as a whole, must be less than that of the air. The specific gravity of the gas and air would vary exactly in the same way under altered pressure, while that of the solid portion of the balloon would be constant; if the barometer fall, the lifting power of the balloon would be lessened; if it rise, it would be increased. Nearly 10000 cubic feet.

15. 124·196 grammes.

17. Water enters the balloon and so makes its specific gravity, as a whole, greater than that of water.. If the opening be above water, pressure will have no effect.

18. Pressure = 17 + 34 feet of water. Volume at atmospheric pressure = 22·5 cubic feet.

20. Depth of centre of gravity = 14·828 inches. Pressure on one side = 597·865 oz.

22. Pressure of mercury = 3⅓ kilogs., pressure of water alone = ⅔ kilogs, pressure of water transmitted through mercury = ⅔ kilogs.; thus, total pressure = 4 kilogs.

23. The law does not hold good, the pressure decreases as the square of the height, the difference is owing to the fact that air is compressed under pressure.

24. In central line 3·45 inches from base. Pressure on base = 187·5 oz.

25. Neglect size of disc; total pressure is due to height of 1033 + 5000 centimetre, therefore pressure on 1 square centimetre = 6033 grammes.

27. ·434 lbs., 21·824 lbs.

28. 612·5 mms.

29. 28·17 lbs.

30. 4·68 inches.

31. 5.05 inches nearly.

32. 32000 c. ft.

G.—SPECIFIC GRAVITY.

1. Specific gravity is the ratio of the density of the body compared with that of water. No. 5·6 lbs.

G 2-31

2. Weight of equal volume of water = 15 grs. of liquid = 12 grs. Specific gravity = ·8.

3. 2·1625.

5. If x = specific gravity of wax $\therefore (2895 + 795) - 390 = \frac{2895}{x} + \frac{795}{2{\cdot}65} \therefore x = {\cdot}965$.

6. ·792.

7. 2·316.

8. 1·204.

10. $\frac{120}{62{\cdot}} \times \frac{5}{4} = 2{\cdot}4$ cubic feet.

11. $\frac{50 + 50 \times {\cdot}8}{96} = {\cdot}9375$.

13. Weigh a cubic inch of metal in air and in water, loss of weight gives weight of 1 cubic inch of water.

14. 62·36 grains.

15. 1·416.

16. It is neutralised by the upward pressure of the liquid.

17. If x = length immersed $\therefore 4\frac{1}{2} \times 1 = x \times {\cdot}915 \therefore x = 4{\cdot}918$ inches.

18. ·08188 inch nearly.

19. See question G5.

20. Here each substance apparently weighs less than its real weight by the weight of an equal volume of water. Thus if x = true weight of glass $\frac{2{\cdot}5 - 1}{2{\cdot}5}\, x = \frac{8 - 1}{8} \times {\cdot}1 \therefore x = 1{\cdot}4583$ lbs.

22. x = depth in denser fluid $\therefore 1{\cdot}2 \times 1 = 1 \times (1 - x) + 1{\cdot}5 \times x \therefore x = {\cdot}4$ inch.

23. Density = mass in unit of volume; specific gravity = ratio between densities.

24. x = length of iron portion $\therefore 21 \times 2 + 7{\cdot}5 \times x = 13{\cdot}5 \times (2 + x - 1) \therefore x = 4{\cdot}75$ inches.

24. Specific gravity = 2·5.

28. Apparent weights are equal, thus $v\ (10{\cdot}47 - 1{\cdot}15 = v^1\ (8{\cdot}89 - 1{\cdot}15) \therefore$ the volume of silver : volume of copper : : 387 : 466.

29. 18 c. inches in each.

30. ·86.

31. $7\frac{21}{22}$ lbs., 56 lbs.

H.—THE BAROMETER, SIPHON, COMMON PUMP, FORCING PUMP, AND AIR-PUMP.

1. One-eighth is removed at each stroke ∴ 7 grains are removed at second stroke.

3. Height of water barometer, because that represents the pressure of the air.

4. Must not be higher than water barometer.

6. The mercury would rise through one inch for every 13½ inches descended.

7. The water will flow towards the narrow end, and will cease when the water is at the same level in the two vessels, or when air ascends into the wide tube.

8. See H6.

9. There is a limit as regards height to the action of the common pump, but not to that of the force pump.

10. x = original volume, volume caused by fall of mercury $= \frac{22}{7} \times \frac{1}{16} \times 5 = 1$ cubic inch nearly, thus volume of air in barometer $= x + 1$, and pressure $= 30 - 25 = 5$ inches of mercury, $\therefore \frac{30}{5} = \frac{x+1}{1}$ $\therefore x = 5$ cubic inches nearly.

12. The height still remains the same, length = 5 feet.

13. Weight of $\frac{1}{48}$ cubic foot of mercury = 282·2916 oz.

15. Weight of 1 cubic inch of mercury = 3436·72 grains.

17. 21·57 lbs. on the square inch nearly, to a height of 51·5 feet nearly.

18. The mercury in the gauge is supported by the pressure of the air in receiver.

19. It would make no difference.

20. (1) The mercury would remain at the same height, being a perfect barometer. (2) The column of air and of mercury would become smaller, the volume of air obeying the law of pressure. (3) The mercury would remain at the same height, being that of the barometer minus the tension of aqueous vapour at that temperature.

21. Explain the air chamber. 2500 lbs.

23. (1) Mercury rises till of same height as before. (2) Mercury runs up the tube till of the same *vertical* height as before.

H 25-43

25. Pressures of enclosed air are 26 and 46 centimetres, volumes of enclosed air are 40 and x cubic centimetres $\therefore 40 \times 26 = 46\,x$ $\therefore x = 22{\cdot}61$ nearly.

26. Receiver will then contain 300 cubic inches; the pressure is increased by 2 atmospheres.

27. The pressure or weight of all the air above a given surface. 1169·256 centimetres.

28. Total pressure $= 29{\cdot}5 + 38 - 4 = 63{\cdot}5$ inches. Volume $= 5 \times \frac{63.5}{29.5} = 10{\cdot}763$ inches.

30. Stop valve in piston, and place valve opening outwards in tube coming from lower part of cylinder.

31. If not vertical, one inch difference of pressure reads more than one inch.

32. Volume varies inversely as the pressure. Pressures are 528 and 408 inches of water, volumes are ·00006 and x cubic inches, $x =$ ·00007764 . . . . cubic inch.

33. $x =$ depression, pressures $= 76$ and x centimetres, volumes $= 10$ and 15 c.c. $\therefore 760 = 15\,x \therefore x = 50{\cdot}6$ centimetres.

34. The air in the pores of the wood expands, and makes the wood, as a whole, of less specific gravity and hence it rises.

36. Volume multiplied by pressure is constant. Difference of pressures $= {\cdot}78$ inches $\therefore$ difference of weight $= 310 \times \frac{{\cdot}78}{30} = 8{\cdot}06$ grains. (100 cubic inches of air $=$ 31 grains at pressure of 30 inches of mercury.

38. If $a =$ height of centre of bubble, $34 - a$ is mean pressure on bubble, and volume will equal $\frac{34 - a}{34 - \frac{1}{2}}$

40. $245\frac{15}{28}$ lbs. $1227\frac{19}{28}$ lbs.

41. 28·03 inches.

42. $\frac{d}{34}$ times more in bell where $d =$ depth in feet of mouth of bell.

43. $9^3 : 10^3$.

K.—OPTICS.

LAWS OF REFLECTION AND REFRACTION.

1. Two images of a candle flame are seen; first is reflected by surface of glass, the second one, which is brighter, by the amalgam.

4. The air is unequally rarefied by the heat, and so thrown into irregular and moving masses having different indices of refraction.

6. The reflecting surface is at right angles to line bisecting angle A B C. The refracted ray is in the same plane as A B C.

7. Three.

8. The ratio between the sine of the angle between the normal and ray of light in that medium, and the sine of the angle between the normal and same ray in air or vacuum.

9. End of rod appears $4\frac{1}{2}$ feet below the surface, hence image is $\sqrt{36 + \frac{81}{4}} = 7\frac{1}{2}$ feet.

10. If at right angles to mirror, its image or the image of any object appears in the same position.

12. When the sine of the angle of incidence in a dense medium is greater than the reciprocal of the index of refraction of that medium, the ray is totally reflected.

13. The incident and reflected rays and the normal are in one plane. The angle of reflection is equal to the angle of incidence.

14. The incident and refracted rays and the normal are in one plane. The ratio between the sines of the angles of incidence and refraction is constant.

15. At a considerable distance the image is very small and at the principal focus; at the centre of curvature the image is equal to the object and at the same spot; at the principal focus the image is infinitely large and may be considered to be at an infinite distance in front or behind the mirror; at the mirror the image is equal to the image and at the same spot (behind the mirror). The changes take place continuously.

16. Prove that it is the the same perpendicular distance behind the mirror that the object is in front.

18. The angle between incident and reflected rays is twice that between incident ray and normal, thus, if this latter angle is increased the former is increased by twice the amount.

K 19-46

19. Make a diagram showing the path of a ray of light from the end of the stick.

20. See K 13.

21. Draw a circle with point of incidence as centre, and from the points of section with incident, reflected and refracted rays, draw perpendiculars to the surface. This produces three similar and equal triangles, and it is seen that the point of incidence is 5 feet from the bright point, and 4 feet from the perpendicular through it.

23. See K 12 and 14.

24. Sine of critical angle = $\frac{3}{4}$.

25. See K 18.

26. His image is erect, virtual and smaller. As he approaches, his image becomes larger and nearer to him.

27. Defects of spherical aberration, and of too great aperture and of inequality in surface.

29. Angle between normal and reflected ray; angle between normal and refracted ray; incident angle in dense medium whose sine equals the reciprocal of index of refraction. Yes.

30. Find by means of sunlight its focal length, twice this distance gives the radius of curvature.

31. See K 13.

33. Shape of pin-hole makes no difference if it be small, as the total image is made up of an immense number of small overlapping spots of light each of same shape as pin-hole.

34. See K 13.

35. The object may be anywhere before the mirror.

36. See K 14. True thickness equals apparent thickness multiplied by the index of refraction.

37. See K 18.

38. Refractive index from water to glass = $\frac{9}{8}$.

40. In the isosceles prism the arrow will point in the opposite direction. In the Woolaston prism, which gives a reflection of a reflection, the arrow will point in same direction as object.

41. See K 13.

42. See K 12.

44. See previous questions.

46. If glass be smooth no light will be lost.

L.—FORMATION OF IMAGES BY MIRRORS AND SIMPLE LENSES.

1. Measure distance of focus produced by means of sunlight from the lens, or, better, measure distance of candle flame and image from the lens, and find f from formula $\frac{1}{f} = \frac{1}{p} + \frac{1}{p'}$. The method would not succeed with a concave lens, as that produces no real image.

3. In the first case it is a virtual erect image, in the second, a real inverted image.

4. To the point from which they first came.

6. See L 1. Focal length = $1\frac{13}{17}$ inches.

8. (*a*) Refracted parallel to the axis, (*b*) passes on in same straight line (if thickness of lens is neglected), (*c*) refracted through other principal focus.

9. The two points are conjugate foci. The sizes are as 25 is to 1.

10. The lens is six inches from the object, and 30 inches from the screen; focal length = 5 inches.

11. At a considerable distance the image is very small, and at the principal focus opposite; at twice the focal length the image equals the object, and is at the same distance at other side; at focus the image is infinitely large, and may be considered to be at an infinite distance, from either side of the lens; at the lens the image is equal to the object, in the same spot at same side of lens. These changes are continuous.

13. The image is real, one-third larger, inverted, and 1 foot in front of the mirror.

14. See L 1.

15. The object is brought to such a distance from the lens, that the image may be formed at the point of distinct vision; the observer's eye is brought close to the lens, so that as much light as possible from the object may enter it.

16. The image is real and inverted.

17. The angular size of the object and image is always the same. Thus we have to find the size of a portion of a sphere whose radius is the focal length of the lens, and which subtends an angle at the centre equal to the angular magnitude of the sun. The image is rendered less bright.

18. If x = distance of object, $2x$ = distance of image $\therefore \frac{1}{f} = \frac{1}{x} + \frac{1}{2x} \therefore x = 18$ inches.

19. Converging lenses are those which cause a parallel beam of light to converge *to* a point, and diverging lenses are those which cause a parallel beam of light to diverge *from* an *imaginary* point. A divergent lens.

20. The image is 4 inches behind the mirror $\therefore \frac{1}{f} = \frac{1}{12} - \frac{1}{4}$ $\therefore -f = 6$ inches.

21. Length = 3 feet.

22. The image is erect if behind the mirror, *i.e.*, if object is between the focus and mirror, but inverted if in front of the mirror, *i.e.*, if object is without the focus.

23. At $\frac{1}{3}$ diameter.

24. See L 22.

25. 12 inches from lens, inverted, 1 inch diameter, $3\frac{3}{4}$ inches behind mirror, $\frac{3}{8}$ inch diameter.

26. 12 inches from mirror, inverted, larger than object, three times as large. At centre of curvature.

27. Midway between object and image.

28. $8\frac{4}{7}$ inches from lens, $\frac{3}{7}$ inch, $15\frac{45}{61}$ inches from second lens, diameter = $\frac{15}{61}$ inch.

30. 3 inches and $1\frac{1}{2}$ inches from mirror.

N.—EXPANSION.

1. 353·355125 cubic inches.

2. About 4°C. The whole water would be reduced to 0°C. before any froze, and then freezing would take place rapidly.

3. 53·31 cubic metres nearly.

4. 209·8 c.c.

5. Coefficient of expansion is the fraction of length expanded in being heated from one fixed temperature to another, say from 0° to 100° C. The mean coefficient of expansion is the average coefficient for each degree between the limits taken. 130·2° C.

6. 531.0119 c.c.

7. 450·531 cubic inches.

9. See 5. Let x = coefficient of linear expansion which is always a very small fraction, x^2 and x^3 are very much smaller fractions and may be neglected in our calculations. $(1 + x)^3 = 1 + 3x + 3x^2 + x^3 = 1 + 3x$ approximately.

10. The temperature at which if the water be heated or cooled its density becomes less.

11. Steel bars outside and one and half times longer than brass bars.

12 Weight thermometer.

O.—THERMOMETERS.

1. − 40° C., 95° F.

2. 29·4° C., − 40° F.

3. 4·4° C., − 40 F.

4. − 40° C. By distilling the liquid under a lower pressure in vacuum pans.

5. Fix on two standard temperatures (those of freezing and boiling water), and divide the difference into any arbitrary number of degrees. − 34·4° C., 163·8° C.

6. The pressure of the air gradually makes the bulb smaller and so causes the mercury to stand higher in the stem than it otherwise would. On being heated the bulb may expand again.

7. Commence with freezing point, otherwise you might cause the bulb to expand beyond its normal size.

8. The glass of the bulb will expand, and so cause the mercury to fall, before it conducts the heat to the mercury and causes it to expand.

9. They will rise on stem owing to contraction of glass.

10. 320°.

Q.—SPECIFIC AND LATENT HEAT.

1. 32° F., because the heat absorbed is used up in converting the ice into water.

2 A liquid boils when the tension of its vapour equals the external pressure ; the tension is increased by rise in temperature, thus the higher the boiling point, the greater is the pressure.

3. Describe any form of calorimeter.

4. See Q 2.

5. 500 grammes.

6. Let x = specific heat of iron.

$\therefore 10 \times 100 \times x = 1000 \times {\cdot}114 \therefore x = {\cdot}114$.

7. 39·5° C.

8. Water and steam under such conditions cannot be made hotter than 100°, any excess of heat is used up in turning the water into steam. 10 oz.

9. Let x = temperature $\therefore (100 - x) = 0{\cdot}033x \therefore x = 96{\cdot}8^{\circ}$ C. nearly.

10. 8000 grammes.

11. 7·95 oz.

13. Let x = latent heat of water $\therefore x + 10{\cdot}3 = 100 - 10{\cdot}3 \therefore x = 79{\cdot}4^{\circ}$ C.

14. In one case the pressure is that of the atmosphere plus 6 inches of water, in the other case the pressure is that of the atmosphere plus 24 inches of water.

15. As 1 is to 715·25 :: 4 : 2861.

16. The height of the mercury in each will be that of the barometer minus the tension of the vapour at that temperature. The order given is the order of their heights.

17. Cold water condenses the steam within, and so lowers the pressure. See 2.

19. The temperature is lowered, the solid salt becoming liquid.

20. Let x = specific heat of copper $\therefore 25 \times 100 \times x = 2{\cdot}875 \times 80 \therefore x = {\cdot}092$.

21. Water so cooled is in an unstable condition. When a portion of the water is converted into ice, the latent heat thus set free raises *the temperature of* the remainder.

22. If we heat a given weight of mercury through a given number of degrees, we use only $\frac{1}{30}$ of the heat required to heat the same weight of water through the same temperature. Let x = temperature $\therefore 100 = 10 \times (20 + x) \times \frac{1}{30} \therefore x = 280^\circ$ C.

23. See Q 2.

24. None.

25. Greater specific heat more slowly body cools.

29. ·10979.

32. The air is warmed, giving increased pressure.

R.—CONDUCTION, CONVECTION, RADIATION.

1. In the first case the water or air appears to carry the heat bodily with it from the furnace to the rooms; in the second case the heat passes through the iron without any sensible motion of the iron.

2. Both are colder than your hand, the mercury conducts the heat rapidly from your hand, while the water does not.

3. The size of the portion seen increases as square of distance, while intensity of light and heat received is inversely as square of distance, the two, therefore, compensate each other.

4. It is possible that the specific heat of the copper is less than that of the iron, and thus with the same quantity of heat communicated to each the copper would be raised to a higher temperature.

5. Glass is not transparent to dark-heat rays while rock-salt is, thus nearly the whole of the heat radiated from the glass comes from a thin slice near the thermopile, but that from the rock-salt comes from all the layers.

6. The air being cooled to a temperature below that at which it is saturated with the aqueous vapour present; anything which causes this cooling to take place rapidly will cause the deposition of dew.

7. (With hour and inch as units, and 79·5 as latent heat of water.) ·207.

9. Owing to difference of specific heat.

10. Leslie's radiometer. Prevost's theory of exchanges.

A.—OXYGEN.

1. $2KClO_3 = 2KCl + 3O_2$. Pass air over baric oxide heated to redness $2BaO + O_2 = 2BaO_2$, pass steam (which acts mechanically) over the baric peroxide, heated rather more. $2BaO_2 = 2BaO + O_2$. Or by mercury to HgO and then decompose.

2. Give test with burning taper and moistened litmus paper.

3. $3MnO_2 = Mn_3O_4 + O_2$; carbonic anhydride $= CO_2$, Water $= H_2O$; phosphoric anhydride $= P_2O_5$; sulphurous anhydride $= SO_2$.

4. Place a stick of phosphorus in the gas over water, it gradually combines with the oxygen, and leaves the nitrogen where present. SO_2, SO_3, CO_2, P_2O_3, P_2O_5, SiO_2 are oxides of an acid nature, and Na_2O, K_2O, F_2O_3 are basic oxides.

5. See A 1. Sulphur, coke, wax, and ammonia can readily be burnt in oxygen, the others will not burn.

7. Pass nitric oxide into the gas. Brown fumes are caused in oxygen, but not in nitrous oxide.

10. (*a*) No. (*b*) Oxide of iron F_3O_4. (*c*) No. Of F_3O_4. (*d*) Yes, either free or combined in Fe_3O_4.

12. 45 grammes nearly.

14. See subject of *the atmosphere* in text books.

B.—HYDROGEN.

1. $2H_2O = 2H_2 + O_2$ by electrolysis. By collecting by displacement with mouth downwards. Water $= H_2O$.

3. Prepare by electrolysis or by sodium and water. By applying a flame or electric spark, when they unite with explosion.

4. Water $= H_2O$, marsh gas $= CH_4$, sal ammoniac NH_4Cl., &c.

5. Burn under a cold bell jar, test the liquid produced; it is tasteless, has no action on litmus paper, and causes potassium thrown upon it to burst into flame.

6. See B 3. Apply a flame, after the combustion shake up with a little lime water, that which contained the hydrogen will remain clear, the other will become milky.

7. See B 6.

C.—CARBON.

1. If each be burned in excess of oxygen, they all produce the same substance CO_2. If powdered and fused with potassic nitrate they all produce potassic carbonate.

2. They are considered to be elements, because hitherto no one has been able to prove that one consists of more than one distinct kind of matter.

3. Heat a portion in a closed crucible, and afterwards exposed to the air; if present in certain forms it will turn black and afterwards burn away. Powder and mix with nitre and drop in portions into a heated crucible, when cold put the mass into a flask, act upon it with dilute sulphuric acid and pass the evolved gas into lime water; if carbon were present it will be turned milky.

4. See C 1.

5. See C 6.

6. (*a*) Try to scratch glass, or better, rock crystal, with it—diamond will scratch it, glass will not. (*b*) Heat in oxygen, diamond will burn, glass will not. Put it in hydrofluoric acid, glass dissolves, diamond not.

7. Oxygen in excess forms CO_2, in defect CO; sulphur forms CS_2.

D.—NITROGEN.

1. Phosphorus combines with the oxygen, leaving nitrogen.

2. Nitre, sal ammoniac, most animal and vegetable substances. Test with a burning taper and lime water.

3. Pass a current of air, dried by being passed through strong sulphuric acid, over copper turnings heated in a glass tube. It combines with the oxygen, leaving nitrogen.

4. See 3. Will not support life, extinguishes a taper.

E.—CHLORINE.

1. $MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2$, pass the gaseous chlorine into water kept at the freezing temperature, a solid hydrate is formed, which on being placed in a sealed tube, and gently heated, splits up into water and liquid chlorine. Cl_2O, Cl_2O_3, Cl_2O_4 and HCl.

2. *i.* bleaches it; *ii.* combines with it forming $CuCl_2$; *iii.* combines with it, forming $SbCl_3$; *iv.* None; *v.* combines with it forming PCl_3 and PCl_5; *vi.* combines with it, forming S_2Cl_2.

4. Chlorine is of a light green colour, bromine vapour of a brown tint; shake up a little ether in each bottle, that in contact with bromine is coloured brown. Chlorine does not exist free because of its strong attraction for other elements, especially hydrogen.

5. They explode, forming two volumes of hydrochloric acid, and one of hydrogen; water dissolves the hydrochloric acid, leaving the hydrogen.

6. *i.* None; *ii.* none except under action of light, when it combines with it, forming HCl sometimes with explosion; *iii.* combines with production of flame, forming PCl_3 and PCl_5; *iv.* none, except under action of sunlight, when it decomposes it. $2H_2O + 2Cl_2 = 4HCl + O_2$; *v.* it decomposes it, $2SH_2 + 2Cl_2 = 4HCl + S_2$; *vi.* it decomposes it, $SO_2 + 2H_2O + Cl_2 = 2HCl + H_2SO_4$.

7. It decomposes water, combining with the hydrogen and setting free oxygen, which being nascent acts more readily than ordinary oxygen.

8. See questions 1 and 2.

F.—BROMINE.

1. Difference in odour. Shake up with water. N_2O_4 gives colourless solution, bromine gives an orange-coloured solution.

G.—IODINE.

1. Iodine liberated. Test it by a solution of starch, which is turned blue by it.

2. Starch paste blue with iodine, yellow with bromine.

3. Heat. Violet vapour shows iodine.

I.—SULPHUR.

1. Native sulphur, iron pyrites, copper pyrites, &c. Extracted by melting out of impurties, and purified by sublimation.

2. Sulphurous acid (= SO_2) is obtained by burning sulphur in a current of air, or for laboratory purposes by heating copper turnings or mercury with sulphuric acid. $Cu + 2H_2SO_4 = 2H_2O + CuSO_4 + SO_2$. 50 grammes of sulphur, and 50 grammes of oxygen.

J.—PHOSPHORUS.

1. By heating out of contact with air for some time. Difference in colour, form, solubility, in carbon bisulphide, and inflammability. Common phosphorus is kept under water because it is spontaneously inflammable at summer temperatures, and continually undergoes slow combustion when exposed to the air.

2. Common phosphorus when heated for some time in a closed tube is converted into red phosphorus, which on being heated still more produces common phosphorus again. Each on boiling with nitric acid form the same compound, phosphoric acid, which on being saturated with sodic hydrate, form from equal weights, equal weights of the same salt.

3. See J 1.

4. P_2O_5. See J 2.

5. See J 2.

I.—COMBINING PROPORTIONS BY WEIGHT AND VOLUME.

2. 58.5, 166, CO_2 = 44, 170.

3. CO, CO_2; CH_4, C_2H_4; SO_2, SO_3; N_2O, N_2O_2, N_2O_3, N_2O_4, N_2O_5.

4. 3797 grains contained, 1627 grains given off.

5. 1 : 2, 1 : 1, 2 : 1, 3 : 1.

6. 444·4 grammes of oxygen, and 55·5 grammes of hydrogen; 622·2 litres of hydrogen and 311·1 litres of oxygen.

7. HCl = 1 vol. H + 1 vol. Cl. H_2O = 2 vols. H + 1 vol O. NH_3 = 3 vols. H + 1 vol. N.

8. Air = 20·8 vols of O + 79·2 vols. of N in 100 vols. 26·26 must be added.

9. 2⅔ grammes = 1·86 litres.

10. 49 grammes.

11. Air contains 23 per cent. by weight of oxygen ∴ ·23 ton of oxygen would burn 193·2 lbs. of carbon.

12. 24 grammes of C. gives 44·8 litres of CO_2.

13. N = 82·35, H = 17·65.

14. 2·29 grammes of P_2O_5, which require 1·19 grammes of O, or 5·61 grammes of air.

15. 200 measures of oxygen = 961·54 measures of air.

16. Zn + H_2SO_4 = $ZnSO_4$ + H_2. 30·77 grammes of hydrogen.

17. *i.* C : H :: 3 : 1; *ii.* C : H :: 6 : 1; *iii.* C : O :: 3 : 8; *iv.* H : O :: 1 : 8.

18. 2 litres of CO, 1 litre of O.

19. 142·86, 125·00, 196·43, 316·96, 75·89 grammes,

20.

Nitrous oxide	N_2O,	N = 63·64	O = 36·36	per cent.
Nitric oxide	N_2O_2,	N = 46·67	O = 53·33	„
Nitrous anhydride	N_2O_3,	N = 36·84	O = 63·16	„
Nitric peroxide	N_2O_4,	N = 30·43	O = 69·57	„
Nitric anhydride	N_2O_5,	N = 25·93	O = 74·07	„

21. NaCl + H_2SO_4 = $NaHSO_4$ + HCl, or 2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl. 62·39 grammes = 38·29 litres. Zn + 2HCl = $ZnCl_2$ + H_2. HgO + 2HCl = $HgCl_2$ + H_2O. MnO_2 + 4HCl = $MnCl_2$ + $2H_2O$ + Cl_2.

22. 20 cu. cm. of O required; 10 c. c. of CO_2 and 20 c. c. of H_2O (steam) produced.

23. Because one atom of O and two atoms of H mutually satisfy one another, and when oxygen replaces hydrogen in a compound, one atom of O replaces two atoms of H.

24. 34 grammes = 22·4 litres.

25. The sum of the atomic weights. 17.

26. In excess of air, water and sulphurous anhydride SO_2, in defect of air, water and free sulphur. 150 c. cms.

27. See L 21. 50 c. c. of chlorine + 50 c. c. of hydrogen. $NaHO + HCl = NaCl + H_2O$.

28. $2NH_4Cl + CaH_2O_2 = CaCl_2 + 2H_2O + 2NH_3$. Density = 8·5. Two volumes of HCl are left, and solid NH_4Cl is formed.

29. One molecule of marsh gas mixed with two molecules of oxygen and exploded, give one molecule of carbonic anhydride (CO_2) and two molecules of water. 75 c. c. of carbonic oxide and 37·5 c. c. of oxygen.

30. The two gases combine together and form 20 c. cms. of steam.

31. $Zn + H_2SO_4 = ZnSO_4 + H_2$; $Zn + 2HCl = ZnCl_2 + H_2$. 3·0675 grammes of H, which produces 27·6075 grammes of water.

32. 36 grammes of water.

33. (*a*) 116 grammes, (*b*) 43·5 grammes, (*c*) 56·1 grammes nearly.

34. On explosion 100 vols. of CO_2 and 100 vols. of O are left. On passing up a ball of caustic potash it absorbs the CO_2, leaving 100 vols. of O. $2KHO + CO_2 = H_2O + K_2CO_3$.

35. There will remain 50 c. cms. of hydrogen and 100 c. cms. of steam.

36. 160 grammes of ammonic nitrate NH_4NO_3 are produced. Chief property production of nitrous oxide on heating.

37 22·4 litres of CO_2 and 36 grammes of water.

38. Fill two tubes of soft glass with mixed gases produced by electrolysis of aqueous hydrochloric acid. Open one under water, it absorbs the chlorine, and rising, fills half the tube; burn magnesium wire before the other and open under mercury, no gas escapes nor does the mercury enter the tube, bring it in contact with water, it dissolves the HCl produced and fills the tube. 18·25 gms.

39. H = 1·59, N = 22·22, O = 76·19 per cent.

40. 60 volumes of oxygen required, 40 volumes of CO_2 produced.

41. 43·12 lbs. nearly.

42. Density = half molecular weight = $\frac{44}{2}$ = 22.

43. 22 grains carbonic anhydride.

44. K .... 38·61
N .... 13·86
O .... 47·52
99·99

45. 300 c. cms oxygen, 400 c. cms CO_2 and 400 c. cms water vapour all measured above 100° C.

46. 188·23 grains SO_2 and 52·94 H_2O.

47. 382906 c. cms H Cl.

48. Density NH_3 = 8·5; 78·57 grains,

M.—GENERAL NATURE OF ACIDS, BASES, AND SALTS.

1. Silica is displaced from its combinations by other acids, as in the preparation of silica by adding hydrochloric, sulphuric or carbonic acid to a solution of water glass. Silica displaces other acids from their combinations by being heated with them, as from nitre, potassic sulphate, moist sodic chloride, &c.

2. Test with litmus paper.

3. Test with litmus paper, by taste, try which can be neutralised by a known acid and a known base.

4. See 3.

5. See 2.

6. See 1.

N.—SYMBOLS AND NOMENCLATURE.

1. H_2O; H_2SO_4; HNO_3; N_2O; SH_2.

2. *(a)* $3\ Fe + 4\ H_2O = Fe_3O_4 + 4H_2$.
(b) $K_2 + 2\ H_2O = 2\ KHO + H_2$.
(c) $2\ Na\ Cl + H_2SO_4 = Na_2SO_4 + 2\ HCl$.
(d) $2\ Cl_2 + 2\ SH_2 = S_2 + 4\ HCl$.

4. H, N, N_2O_3, C, CH_4, Cl, Br, P, P_2O_5, SiO_2.

5. H_2O, NH_3, SiO_2, CO_2 or H_2CO_3, H_2SO_4, CH_4, PH_3.

6. *(a)* $H_2SO_4, + NaCl = NaHSO_4 + HCl$
or $H_2SO_4 + 2\ NaCl = Na_2SO_4 + 2\ HCl$.
(b) $2\ H_2SO_4 + 2\ NaCl + MnO_2 = MnSO_4 + Na_2SO_4 + 2\ H_2O + Cl_2$.
(c) $NH_4NO_2 = N_2 + 2\ H_2O$.
(d) $NH_4NO_3 = N_2O + 2\ H_2O$.

7. M_2SO_3, M_2SO_4; MNO_2, MNO_3; N_2O, N_2O_2. (M = metal as sodium.)

8. $H_2SO_4 + 2\ NaCl = Na_2SO_4 + 2\ HCl$.
$H_2SO_4 + 2\ NH_4Cl = (NH_4)_2\ SO_4 + 2\ HCl$.
$H_2SO_4 + 2\ KNO_3 = K_2SO_4 + 2\ HNO_3$.
$2\ H_2SO_4 + Cu = CuSO_4 + 2\ H_2O + SO_2$.

9. Nitrogen 77 oxygen 23 per cent, SiO_2, $CaCO_3$, NH_3, CH_4, C, carbonic oxide, nitric oxide, sulphurous anhydride, nitrous anhydride (acid), sal ammoniac, or ammonic chloride.

O.—THE ATMOSPHERE, &c.

1. 12·48 cu. in. of oxygen. Nitrogen and a little CO_2, H_2O and NH_3.

2. A mixture made in the same proportions neither absorbs nor gives out heat, has the mean properties of its constituents, and cannot be distinguished from ordinary air. The air dissolved by water contains a much larger per centage of oxygen than ordinary air, which it would not do if it were a compound.

3. Oxygen is removed from the air by the respiration of animals (also that of plants in the dark) and by the processes of combustion and decay, it is restored to the air again by plants during the assimilation of CO_2 in sunlight.

4. Water by passing air through a cooled tube, or tube containing a drying substance. Carbonic acid by production of film on basin of lime water exposed to the air. Oxygen by production of brown fumes on allowing nitric oxide to escape into the air. Nitrogen by removing other constituents and testing the remaining gas with lime water and a taper.

5. By heating mercury in a confined portion of air, red oxide of mercury was formed which on being heated still further gave up the amount of oxygen it had previously lost.

6. See 1 and 2.

7. See 5. 20·8 c.c. of oxygen. 41·6 c.c. of hydrogen.

8. See 3.

9. Nitrogen passes through unchanged, oxygen and carbonic acid and water form hydrogen and carbonic oxide, $CO_2 + C = 2\ CO$, $H_2O + C = H_2 + CO$.

10. See 2.

11. Animals take oxygen from the air and give up carbonic acid and water to it. The higher the temperature and lower the pressure the greater is the quantity of aqueous vapour present in the air.

12. See 2.

13. See 11.

14. See 2.

P.—COMBUSTION, &c.

1. A candle requires oxygen, with which to combine in the act of burning, when the oxygen present is used up, the candle ceases to burn. The iron or copper combines with the oxygen, leaving nitrogen. 16 grammes of oxygen = 69·565 grammes of air.

2. In the Bunsen's burner the mixture of air and gas is burnt rapidly, so that heavy soot-forming hydrocarbons are not formed; in the common gas-light this rapid combustion can only take place at the exterior, the heat thus formed and the partial combustion of the remainder causes the production of heavy hydrocarbons and heats them to such a degree that they give out light.

3. Products are water, carbonic anhydride, and a little sulphurous acid.

4. See 2.

5. Sulphurous anhydride SO_2; Phosphorous anhydride P_2O_3; Phosphoric anhydride P_2O_5; Water H_2O; Carbonic oxide CO; Carbonic anhydride CO_2.

6. The surface of the flame is in contact with a plentiful supply of oxygen, in which the whole of the gas is burnt, the inner part has a very limited supply, in which only a portion of the hydrogen is burnt.

7. See 3. Without a glass sufficient air does not reach the flame to totally burn the gas, smoke and soot being produced; a glass increases the current of air, the gas is totally burnt, and so more light and heat are produced in the same time.

8. Burn anything in a closed bottle, when the oxygen is used up, the combustion ceases, even if the combustible be strongly heated. The oxygen combines with it. Distil it with carbon, phosphorus and carbonic oxide, a body known to contain oxygen, are produced.

9. See 7.

11. See previous questions.

Q.—WATER.

1 Hydrogen = twice volume or one-eighth weight of the oxygen.

2. Water can be produced by combining oxygen and hydrogen, and can be decomposed into oxygen and hydrogen by electrolysis.

3. Rain water is much purer than sea water, containing very little if any solid dissolved. Calcic carbonate and sulphate, sodic chloride, ammonia and nitrates. By distillation. Boil in a flask, fitted with tube which dips into a solution of some salt of lead; if sulphuretted hydrogen is present it soon comes off and blackens the solution.

4. The sea-water was distilled, and the distilled water was aërated by being passed through porous carbon filters. Sodic chloride, magnesic chloride and sulphate, calcic carbonate and sulphate, a little combined bromine and iodine.

5. Inability to form a lather with soap owing to the presence of lime or magnesia salts. By Clark's soap test.

6. See 2.

7. The hardness is chiefly caused by calcic carbonate, rendered soluble by excess of carbonic acid, this excess combines with the lime added, and thus the whole of the calcic carbonate is precipitated.

8. See 7.

9. The precipitate is calcic carbonate, which was dissolved in the water by excess of carbonic acid, when this was expelled by boiling it was rendered insoluble.

10. See previous questions.

11. To equal portions of the same solution of nitrate of silver, acidified with nitric acid, add the water, drop by drop, as long as a precipitate is formed; that water the least quantity of which sufficed is sea water. Add a little solution of soap in spirits of wine to portions of each of the other waters and shake well, in the soft water little curds but much lather is produced, in the hard little lather but much curds.

13. Water dissolves oxygen, and gives it up again to water, blood, or other liquids containing proportionally less than it does. Place fish in water under an air-pump and exhaust, or pour oil on the surface of the water, in either case air has no access to the water, and the fish die.

14. Pass hydrogen over heated copper oxide. See text books.

15. More calcic carbonate being present more is dissolved. The lime water precipitates the CO_2, and solvent being destroyed, the calcic carbonate dissolved is thrown down. See Clark's process for softening waters given in text books.

R.—CARBONIC ACID, CARBONIC OXIDE.

1. CO_2 is chiefly produced, probably a little CO and H are also formed. In the upper portion of the fire CO and H form the main portion of the products.

2. Burn magnesium in it, magnesia, known to contain oxygen, and carbon are formed. $Ca\,CO_3 + 2\,H\,Cl = H_2O + CO_2$. Lime water becomes milky when shaken with CO_2 but not with N.

3. See 2. 22 times as heavy.

4. See 2. Add lime water to the spring water, if carbonic acid were present, a precipitate would be produced.

5. Nitrogen, steam, carbonic oxide, carbonic anhydride.

6. Volcanoes, decay, respiration of animals; the assimilation of carbon from the carbonic acid by plants under the influence of sunlight.

7. Pass CO_2 over coke, iron, &c., heated to redness.

8. Shake up with lime water, a precipitate is produced in bottle containing CO_2; apply a flame, CO burns with a blue flame.

9. See 5. On shaking up with lime water it should produce a precipitate, and on standing over a solution of caustic potash it should be nearly wholly absorbed.

10. See 9.

11. See 2. $CO_2 + C = 2\,CO$.

S.—OXIDES AND ACIDS OF NITROGEN.

1. Cupric nitrate CuN_2O_6, water H_2O and nitric oxide N_2O_2; it combines with the free oxygen forming N_2O_3 and N_2O_4.

2. Pass nitric oxide into it, red fumes are produced in oxygen not in nitrous oxide.

3. Because none have, as yet, been decomposed into simpler forms of matter. Pass nitric oxide into it; if a mixture red fumes are caused by the free oxygen; if a compound they are not produced.

4. $KNO_3 + H_2SO_4 = KHSO_4 + HNO_3$. We suppose that hydrogen is really produced but that it then causes more nitric acid to be decomposed, combining with oxygen and liberating lower oxides of nitrogen. Combination ensues, water and a salt, potassic nitrate, being formed.

5. By heating ammonic nitrate. See 2.

6. See 4. Potassic nitrate and water are formed, nitrite one atom less oxygen than nitrate.

7. KNO_3, KNO_2, see 4. One atom oxygen.

T.—AMMONIA.

1. A gas obtained by heating a mixture of lime and sal ammoniac, composed of 14 parts by weight of nitrogen united to 3 parts of hydrogen; or by volume 1 part of nitrogen to 3 parts of hydrogen.

2. $2\,NH_4Cl + CaH_2O_2 = CaCl_2 + 2\,H_2O + 2\,NH_3$. 1 cubic inch of HCl.

3. Free, heat alone; combined, heat with addition of caustic potash, and hold red litmus paper in the vapour, if ammonia be present it will change the colour to blue.

4. See 2.

5. *(a)* It is dissolved probably forming a hydrate, on boiling the solution the gas is again given off; *(b)* it combines with it forming the salt, ammonic sulphate, the gas is given off on heating this salt with lime.

7. Add 17 volumes of oxygen in eudiometer and explode, water formed showing hydrogen, remaining gas has all the properties of nitrogen.

U.—OLEFIANT GAS, MARSH GAS.

1. By heating alcohol with strong sulphuric acid; 6 parts of carbon by weight to one part of hydrogen; on explosion with excess of oxygen each volume produces two volumes of carbonic anhydride.

2. By heating a mixture of sodic acetate, caustic soda and quicklime. 400 vols., 200 vols. of oxygen and 200 vols. of carbonic anhydride.

3. See 1. Explode equal volumes of the two gases with an excess of oxygen, and then absorb the CO_2 produced with a solution of caustic potash, this will produce a diminution in the case of olefiant gas, twice as great as in that of marsh gas.

V.—SULPHUROUS AND SULPHURIC ACIDS.

1. Add a little hydrochloric acid and then a solution of baric chloride, if sulphuric acid be present a precipitate is produced.

2. Burn sulphur in oxygen, or deoxidise sulphuric acid by heating it with copper. A taper does not burn in it and it bleaches flowers.

3. See text books.

4. HNO_3 and $BaCl_2$, HNO_3 and $AgNO_3$, PbN_2O_6 black precipitate, H_2SO_4 and $FeSO_4$.

5. Sulphurous anhydride; by dissolving it in water and heating with nitric acid. See 1.

6. Sulphurous anhydride SO_2, forms with water sulphurous acid H_2SO_3, and with sodic carbonate, sodic sulphite Na_2SO_3 and CO_2. Sulphuric anhydride SO_3, forms with water sulphuric acid H_2SO_4 and with sodic carbonate sodic sulphate Na_2SO_4 and CO_2.

7. (1) SO_2, SO_3. (2) H_2SO_3, H_2SO_4. (3) K_2SO_4, $KHSO_4$, K_2SO_3, $KHSO_3$, add hydrochloric acid, then a solution of baric chloride, a precipitate is produced by the sulphate, and not by the sulphite.

W.—SULPHURETTED HYDROGEN.

1. By acting on ferrous sulphide with dilute sulphuruc acid in a Woulff's bottle. $FeS + H_2SO_4 = FeSO_4 + SH_2$. In excess SO_2 and H_2O, in defect S and H_2O.

2. Heat in flask and pass vapours through a solution of plumbic acetate; sulphuretted hydrogen, if present, blackens the solution.

3. See. 1. Pass it through a heated tube containing cupric oxide, cupric sulphide and water, substances known to contain sulphur and hydrogen respectively, are formed; or explode with oxygen. It produces a precipitate of plumbic sulphide and liberates nitric acid.

4. Hold cold glass over burning jet of gas when water condenses. Hold a pansy, violet or sheet of litmus paper over fumes, bleaching shows SO_2, peculiar smell of burning brimstone is decisive of SO_2 and hence of sulphur.

X.—HYDROCHLORIC ACID.

1. By weight hydrogen 2 parts, chlorine 71 parts; by volume equa parts.

2. See L 21. One volume of chlorine plus one volume of hydrogen form two volumes of hydrochloric acid. Water dissolves the gas, forming a solution having many of the properties of the gas.

3. See L 21. Add a little nitric acid and solution of argentic chloride, a white precipitate is produced in the hydrochloric acid.

4. Apply a burning taper, this would cause the mixture to combine, but the taper would be extinguished in the compound. Test with blue litmus, the mixture would bleach it, the compound would redden it, &c.

6. See L 38.

7. See previous questions, NH_3 known to be present by heating and holding red litmus paper over solution, when it will change from red to blue.

Y.—PHOSPHORIC ACID AND PHOSPHURETTED HYDROGEN.

1. Phosphoric anhydride P_2O_5. It first becomes metaphosphoric acid HPO_3 and ultimately orthophosphoric acid H_3PO_4.

2. Water is decomposed, its hydrogen unites with phosphorus, forming liquid and gaseous phosphuretted hydrogen, and its oxygen unites with phosphorus and lime forming calcic hypophosphite. When kept at a low temperature the liquid phosphuretted hydrogen becomes condensed, the gaseous is not spontaneously inflammable.

Z.—SILICA.

1. Fused with a mixture of sodic and potassic carbonates, dissolve in dilute hydrochloric acid, it may be rendered insoluble again by evaporating to dryness.

2. See M 1.

3. See M 1 and Z 1.

A′.—NOT CLASSED.

1. See A 4.

2. Apply a burning taper, this would cause an explosion to occur if the gases were present in proper proportions, or would cause it to burn or would burn in it according as hydrogen or oxygen was in excess; the taper would be simply extinguished in the compound. Reduce to ordinary temperatures, the mixture would remain as gas, the compound a liquid.

3. Add a little chlorine water and a few drops of bisulphide of *carbon and shake, if* the bisulphide of carbon remain uncoloured the *chloride was present, if* brown the bromide and if violet the iodide.

4. By aid of a microscope the separate particles of iron and sulphur could be distinguished in the mixture but not in the compound. A magnet would separate the iron from the sulphur in the mixture, not in the compound. Bisulphide of carbon would dissolve the sulphur of the mixture, not that of the compound. Pour dilute hydrochloric acid over them, hydrogen would be given off from the mixture, and sulphuretted hydrogen from the compound.

5. Add hydrochloric acid, no gas would be given off by the chloride, the carbonate would give off a gas having, at most, a slightly pungent odour, while the sulphide would give off a gas of a disgusting odour.

6. $FeS + H_2SO_4 = FeSO_4 + SH_2$; $Na_2SO_3 + H_2SO_4 = Na_2SO_4 + H_2O + SO_2$.

7. See 4.

INDEX TO DETERMINE DATE OF QUESTIONS IN NATURAL PHILOSOPHY.

Example.—The 10th question of the January paper for 1872 is the 20th question of Class H.

DATE.		NUMBER OF QUESTION.															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1864	January	A_1	C_1	B_1	E_1	F_1	*	H_1	L_1	Q_1							
	June	A_2	B_2	C_2	E_2	F_2	H_2	*	K_1	L_2							
1865	January	B_3	A_3	C_3	E_3	G_1	H_3	*	K_2	O_1							
	June	B_4	C_4	B_5	E_4	H_4	F_3	*	K_3	K_4	Q_2						
1866	January	A_4	C_5	B_6	D_1	G_2	H_5	H_6	L_3	N_1							
	June	A_5	C_6	B_7	D_2	E_3	H_7	H_8	*	K_5	N_2	Q_3					
1867	January	A_6	B_8	C_7	D_3	E_5	H_9	G_4	*	L_4							
	June	A_7	B_9	C_8	E_6	F_4	G_5	H_{10}	*	K_6	O_2						
1868	January	A_8	B_{11}	C_9	E_7	G_6	H_{11}	H_{12}	*	L_5							
	June	A_9	B_{10}	C_{10}	E_8	G_7	H_{13}	H_{14}	*	K_7	Q_4						
1869	January	D_4	A_{10}	C_{11}	B_{12}	E_9	G_8	H_{15}	*	K_8	N_3						
	June	E_{10}	B_{13}	C_{12}	A_{11}	D_5	F_5	F_6	*	L_6	Q_5						
1870	January	A_{12}	B_{14}	C_{13}	D_6	F_7	H_{16}	*	K_9	Q_6							
	June	A_{13}	B_{16}	B_{15}	D_7	H_{17}	F_8	H_{18}	L_7	O_3							
1871	January	A_{14}	B_{17}	$C_{13}a$	E_{11}	D_8	F_9	F_{10}	L_8	Q_7							
	June	A_{15}	B_{18}	B_{19}	E_{12}	D_9	D_{10}	F_{11}	G_9	F_{12}	K_{10}	K_{11}	K_{12}	R_1			
1872	January	A_{16}	A_{17}	B_{20}	D_{11}	D_{12}	D_{13}	F_{13}	G_{10}	H_{19}	H_{20}	K_{13}	K_{14}	K_{15}	Q_8		
	June	A_{18}	A_{19}	A_{20}	B_{21}	D_{14}	D_{15}	A_{21}	H_{21}	G_{11}	F_{14}	K_{16}	K_{17}	L_9	R_2		

INDEX TO DETERMINE DATE OF QUESTIONS IN NATURAL PHILOSOPHY—*continued.*

DATE.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1873	January	B_{22}	B_{23}	A_{22}	D_{16}	D_{17}	B_{24}	G_{12}	G_{13}	F_{15}	K_{18}	K_{19}	L_{10}	Q_9			
	June	A_{23}	C_{14}	B_{25}	D_{18}	D_{19}	D_{20}	G_{14}	F_{16}	F_{17}	K_{20}	K_{21}	L_{11}	Q_{10}			
1874	January	A_{24}	B_{26}	B_{27}	D_{21}	D_{22}	D_{23}	G_{15}	G_{16}	F_{18}	K_{22}	K_{23}	L_{12}				
	June	A_{25}	A_{26}	A_{27}	D_{24}	D_{25}	E_{13}	G_{17}	H_{22}	H_{23}	L_{13}	K_{24}	L_{14}	N_4			
1875	January	A_{28}	B_{28}	C_{15}	D_{26}	E_{14}	D_{27}	G_{18}	H_{24}	H_{25}	K_{25}	K_{26}	L_{15}	Q_{11}			
	June	A_{29}	C_{16}	A_{30}	D_{28}	D_{29}	D_{30}	G_{19}	G_{20}	H_{26}	K_{27}	K_{28}	L_{16}	O_7	Q_{13}	Q_{12}	N_5
1876	January	C_{17}	B_{29}	A_{31}	E_{15}	D_{31}	D_{32}	G_{21}	G_{22}	H_{27}	H_{28}	K_{29}	K_{30}	R_3	O_6	Q_{14}	$\left\{\begin{matrix}Q_{15}\\N_4\end{matrix}\right.$
	June	A_{32}	A_{33}	A_{34}	E_{16}	E_{17}	F_{19}	F_{20}	G_{23}	Q_{16}	Q_{17}	N_6	Q_{18}	Q_{19}	K_{31}	L_{17}	K_{32}
1877	January	A_{35}	C_{18}	A_{36}	D_{33}	D_{34}	E_{18}	G_{24}	H_{29}	H_{30}	H_{31}	N_7	Q_{20}	R_4	K_{33}	K_{34}	L_{18}
	June	D_{35}	C_{19}	A_{37}	D_{36}	D_{37}	F_{21}	F_{22}	A_{38}	H_{32}	G_{25}	N_8	N_9	R_5	K_{35}	K_{36}	L_{19}
1878	January	B_{30}	B_{31}	A_{39}	E_{19}	E_{20}	G_{26}	F_{23}	H_{33}	H_{34}	N_{10}	R_6	Q_{21}	Q_{22}	K_{37}	L_{20}	K_{38}
	June	A_{40}	B_{32}	D_{38}	D_{39}	D_{40}	G_{27}	F_{24}	G_{28}	F_{25}	H_{35}	H_{36}	L_{21}	L_{22}	O_8	N_{11}	Q_{23}
1879	January	C_{20}	C_{21}	A_{41}	A_{42}	E_{21}	D_{41}	F_{26}	F_{27}	H_{37}	H_{38}	K_{39}	K_{40}	L_{23}	N_{12}	Q_{25}	Q_{24}
	June	E_{22}	E_{23}	D_{42}	A_{43}	B_{33}	A_{44}	G_{29}	H_{39}	H_{40}	F_{28}	O_9	Q_{26}	R_8	K_{41}	L_{24}	L_{25}
1880	January	A_{45}	A_{46}	C_{22}	D_{43}	E_{24}	F_{29}	G_{30}	H_{41}	K_{42}	K_{43}	L_{26}	L_{27}	O_{10}	Q_{27}	Q_{28}	R_7
	June	D_{44}	A_{47}	C_{23}	E_{25}	E_{26}	G_{31}	F_{30}	F_{31}	H_{42}	K_{44}	L_{28}	L_{29}	Q_{29}	Q_{30}	R_9	R_{10}
1881	January	D_{45}	A_{48}	B_{34}	C_{24}	D_{46}	F_{32}	G_{32}	H_{43}	H_{44}	K_{45}	K_{46}	L_{30}	P_1	Q_{31}	Q_{32}	R_{11}

Classes M, N, O, P, Q, R, were until June, 1875, included under Chemistry. In the Index, the numbering of the Questions in these classes previous to June, 1875, has been altered, thus:—Question 1 of the January Chemistry Paper for the year 1864, is put as Question 9 of the Natural Philosophy Paper of that year.

* Indicates that the question under which it is placed was one in Acoustics, a subject formerly included in the Matriculation Examination.

INDEX TO DETERMINE DATE OF QUESTIONS IN CHEMISTRY.

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NOTE.—Until June, 1875, Questions in Heat were included in the Chemistry Paper. These have been transferred to Natural Philosophy—see Index to Natural Philosophy Questions.

DATE.		NUMBER OF QUESTION.							
		1	2	3	4	5	6	7	8
1864	January		O_1	Q_1	R_1	E_1	I_1		
	June	A'_5	Q_2	L_1	C_1	A_1	X_1	D_1	
1865	January		O_2	L_2	N_1	N_2	T_1		
	June		A_3	A_2	L_3	R_2	O_3	L_4	L_5
1866	January		P_1	M_1	B_1	L_6	O_4	P_2	R_3
	June		N_3	O_5	L_7	M_2	J_1	P_3	B_2
1867	January	A_4	B_3	Q_3	P_4	C_2	A'_2	L_8	L_9
	June	A_5	L_{10}	N_4	E_2	L_{11}	X_2		D_2
1868	January	O_6	E_3	M_3	L_{14}	L_{12}	R_6	L_{13}	
	June		Q_4	R_5	I_2	T_2	L_{15}		
1869	January		B_4	N_5	R_6	X_3	V_1	Z_1	
	June		O_7	L_{16}	R_7	S_1	T_3	W_1	L_{17}
1870	January	A_7	Q_5	T_4	L_{18}	P_6	C_3	V_2	
	June		L_{20}	L_{19}	V_4	P_5	N_6	V_3	
1871	January		Q_6	A_8	N_7	W_2	L_{21}		
	June		S_3	V_8	P_6	Q_7	J_2	L_{22}	
1872	January		O_8	L_{23}	E_4	S_4	L_{24}		
	June		L_{25}	A_9	G_1	O_9	L_{27}	L_{26}	

INDEX TO DETERMINE DATE OF QUESTIONS IN CHEMISTRY—*continued.*

DATE.		1	2	3	4	5	6	7	8
1873	January		O_{10}	B_5		Y_1	R_8	L_{28}	
	June		C_4	E_5	P_7	Q_8	L_{29}		
1874	January		A_{10}	L_{30}	Z_2	O_{11}	Y_2		
	June		P_8	M_4	S_5	C_5	L_{31}		
1875	January		X_4	O_{12}	R_9	L_{32} & Q_9	W_3		
	June	L_{33}	Q_{10}	L_{34}	U_1	A'_3	N_8		
1876	January		L_{33}	X_5	L_{36}	A'_4	V_6		
	June	D_3	L_{37}	C_6	V_7	E_6	Z_3		
1877	January	A_{11}	L_{38}	T_5	C_7	U_2	A'_5		
	June	O_{13}	L_{39}	X_6	A'_6	L_{40}	Q_{11}		
1878	January	Q_{12}	J_3	L_{41}	E_7	U_3	Q_{13}		
	June	A'_7	B_6	O_{14}	J_4	P_9	R_{10}		
1879	January	N_9	L_{42}	G_2	A_{12}	S_6	L_{43}		
	June	A_{13}	D_4	G_3	T_6	W_4	P_{10}	L_{44}	L_{45}
1880	January	E_8	I_3	Q_{14}	P_{11}	R_{11}	M_6	L_{47}	
	June	B_1	L_{46}	M_5	Q_{15}	S_7	C_8		
1881	January	A_{14}	J_5	F_1	T_7	L_{48}	X_7		